The dynamic theory of life and mind

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THE

DYNAMIC THEORY

OF

LIFE AND MIND

An attempt to show that all Organic Beings are both Constructed and Operated by the Dynamic Agencies of their respective Environments.

BY

JAMES B. ALEXANDER.

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PREFACE.

It is about a generation since the ideas of the selection of species by natural causes took such form as to constitute a theory. Although Chas. Darwin has received the credit of this theory, and no doubt deserves it, yet the fact is, the theory was in the air as we may say and was discovering itself to a great many people at the same time. That is to say, the great body of accumulated natural facts that constituted a part of the environment of all thinking and well-informed people, impressed itself in a somewhat similar manner upon many at once and was evolving in their brains similar reactions. A. R. Wallace was almost as ready as Darwin to announce the theory and would have done so had he not been anticipated. But if neither of these gentlemen had been in the way of this idea it would soon have obtained expression by someone else. So ready was the rationalistic world for it that it was received with little or no hesitation; its simple announcement and explanation being all that was required.

The history of this theory is itself a good illustration of the Dynamic Theory. Things come about naturally and as a matter of course when due forces become organized to operate on properly organized instruments. In this case the facts were the forces and men's brains the instruments.

The complete acceptance of this theory largely withdrew attention from the essential facts and causes underlying selection. Some of these facts incidentally presented themselves in the discussions and explications of the theory, but usually too little account was taken of them, the attention being concentrated on the struggle for life between competing organisms. Unless it is qualified, this expression, "struggle for life," is itself misleading, as it seems to imply that the organism is an original center of activity and does something of itself.

It is my endeavor in this volume to point out that organisms instead of being hand-made and purposive, are machine-built machines, and operated, when built, by forces outside of themselves. As we are more interested in ourselves than in other organisms, especial care has been taken to ascertain the relationship of man to the other animals and to point out their resemblances and contrasts. To this end I have cited a large number of *facts* that cannot fail to interest every intelligent person whether he agrees with my conclusions or not.

Especial attention is called to mental phenomena and the machinery for their production. The brain is shown to be the organ of the environ-

ment and a mind forming instrument. Our ancestors were in the habit of looking entirely too high for the explanation of the phenomena of sensation and mind. They never dreamed that these were physical phenomena, or connected in any way with the motions of material bodies with which they were familar. The true course of knowledge is not from above downward, but from below upward, and but little progress is possible where this principle is ignored. The advancement of the present generation has been greatly assisted by its partial emancipation from the dominance of the past with its essentially vicious metaphysical methods. The study of dynamic agencies and the inferences justified by the inductive method of considering them, furnish us with all the real knowledge of causes and effects that we possess. We easily connect these agencies with the motions that constitute vitality and mentality and discover that the energies of the environment constitute the antecedents of specialized function. As these energies build up bodies of different shapes, the forms of the reactions from them correspondingly change. We have motion before we have locomotion and we have locomotion before legs; we have circulation before hearts, nerve currents before nerves, and mental action before brains. Thus function operates in the modification of organs and by cumulation of modifications in their re-creation.

The Dynamic Theory, by showing the connection between the external stimulation and its internal sequel in mental action, proves both of them to belong to the same class of physical motion. A study of mental action therefore demands and includes an investigation of the related and antecedent physical phenomena. When these are all considered together we soon perceive that they belong together. Particularly are the phenomena of mentality and vitality seen to be inseparable. In fact all organic reactions partake of both vital and mental characteristics, and when we consider the more elementary organisms, the two merge into each other till it becomes impossible to make any distinction between them. A similar consideration extended to other branches of physical phenomena show them to be all derived from a common stock, and that finally we must consider all energy as only one.

Finding ourselves involved in the effects of these various dynamic agencies, the study of them and the ways in which they affect us, becomes a matter of personal interest to everyone; and it is not too much to say that it is a duty everyone owes to himself to pursue such study as far as practicable. It is a sort of duty that, like eating, breathing or exercising, cannot be delegated or performed by proxy; and its neglect involves an abdication not only of power, but of liberty.

The facts I have presented have been drawn from the most reliable scientific authorities. The following list includes those most quoted:

Abercrombie, Agassiz, Bain, Barker, Barnard, Bastian, Bernstein, Bessey, Binet and Fere, Bjerkness, Brown-Sequard, Carpenter, Charcot, Capt. Clark, Claus, Combe, J. P. Cooke, Cooke & Berkley, Crookes, Cuvier, Dana, Darwin, Dawson, Draper, Dubois-Raymond, Dunglison, Eliot & Storer, Ferrier, Flint, Gage, Geddes & Thomson, Gordon, Asa Gray, H. Gray, Gurney, Hæckel, Huxley, Landois, Langley, Leckey, Le Conte, Letourneau, Lewes, Lockyer, Lubbock, Luys, Maudsley, Meyer, Max. Müller, Murdock, Nott & Gliddon, Owen, Packard, Papillon, Pasteur, Pepper, Plante, Pop. Sci. Mo., Quain, Romanes, Roscoe, Rosenthal, Schützenberger, Semper, Dr. Shepherd, Skeat, Spencer, Dr. Star, B. Stewart, Sully, Isaac Taylor, Tellor, S. P. Thompson, Tyndall Van Beneden, Velpeau, Vogel, Wagner, Wallace, Warner, Watts, Wilder, Wilson, Wurtz, Youmans. Besides the foregoing, from the works of some of whom copious extracts have been made, many other authorities have been quoted whose names are mentioned in the proper connection. Thus a broad basis of fact has been laid for the conclusions that have been reached, and it is for the reader to judge whether the facts justify the conclusions, or to frame others if they do not.

It is not likely that the work has entirely escaped errors of statement, and if there are any the writer will be glad to have them pointed out to him.

J. B. A.

MINNEAPOLIS, MINN.,
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CONTENTS.

DYNAMIC THEORY OF LIFE AND MIND.

CHAPTER I.

INTRODUCTORY.

The action of the mind has always appeared to be involved in such obscurity, to be so whimsical and so uncertain, that ordinarily, until lately, it has been looked upon as something inscrutable and outside of investigation.

The mind itself has generally been regarded as a person; one of the two persons of an animal duality which is commonly supposed to be made up of a mind and a body. The body has been recognized as being material, subject to natural law, and liable to accident, disease, decay and death. The mind has generally been considered as exempt from all these accidents, especially the last, and to be immaterial, immortal and indestructible. If it was ever thought to be subject to law, it was no such law as anybody could find out anything about, and not at all analogous to laws that govern material things. Although mental diseases were vaguely spoken of, it was only meant that the body was out of order, by which the mental action became distorted; and that after death, when the mind should be rid of the incumbrance of the diseased body, it would itself be thereafter forever free from disease. The terms used to designate this part of the supposed dual being are also various—as mind, soul, spirit. Some who use these terms profess to make distinctions in their significance, but generally they are used indiscriminately to mean the part of the man (or animal) that does the thinking. Notwithstanding this thinking part is thus supposed to be the real man, while the body is only its tool or instrument, our daily language shows how vaguely the idea is held, for we speak of a man "making up his mind," "changing his mind," "altering his judgment," &c., as if the man were superior to his mind and had some sort of supervisory control over it. It is generally held that a man is a free agent and "can do as he pleases;" that he can change his plans, alter his opinions, and regulate his conduct according to his "will;" and this will is the main sovereign energy of the inscrutable mind, soul or spirit. This will is above

reason, and may defy all cause and set aside all law. Nevertheless we are continually talking about bringing influences to bear to change men's wills, arguments to alter their opinions, and inducements to modify or regulate their actions. We also seem by our language to expect that causes will influence the will and alter the actions; in such expressions as "What could have caused that man to act so?" "Whatever possessed him?" "Knowing as he did, why did he not do thus and so?" What inducements can we offer? The vagueness and confusion of the current ideas on the subject of the mind are clearly traceable to two impossibilities. The first is the impossibility of conceiving of any being or thing short of infinite, not subject to the operations of cause and effect, in short, not subject to law; the other is the impossibility of conceiving of an immaterial being or thing as being subject to any law or influence whatever; not to say the impossibility of conceiving of the existence of such a being at all.

I believe the present state of knowledge to be sufficiently advanced to furnish plausible, if not demonstrative, proof that the mind is not a person or thing at all, but that mental action is a form of physical energy. This theory would take mental action out of the region of fancy, whim and caprice, and place it along with everything else in nature, under the dominion of law which we can learn to watch in its operations and trace in its certain and inevitable effects.

In studying man, we shall find that we cannot separate him from his surroundings, and that to understand him we must understand them. Moreover, without hesitation we admit the analogy between one man and another, and expect to find the general characteristics of the race in every individual. The ancients went this far; but modern discovery enables us to go much further, and confidently to regard every animal as the analogue of man; so that we study ourselves when we study them.

CHAPTER II.

OUR RELATIONS.

The first step in the argument is to show the intimate relationship existing between man and the rest of animated creation, to prove his kinship to the other animals, and to demonstrate his origin and development to be identical with theirs.

There are many general points of resemblance between man and other animals that are patent to the most ordinary observation. Thus he resembles all in requiring food, in digesting it, in excreting the waste, in requiring the rest and refreshment of sleep, in growth from infancy to maturity, in the reproduction of his kind, in the decay of old age, and

finally in death. Men and other mammals are so near alike that they are subject to the same diseases, such as lung fever, and may be treated with the same medicines. They catch each other's contagious diseases, such as hydrophobia, variola, glanders, syphilis, cholera, splenic fever, milk sickness, herpes, &c.

They are alike subject to periodic influences and cycles, monthly, weekly, &c.

If we single out the higher orders of animals with which to compare man, as we go up the scale the more striking and minute the resemblances become. Compared with mammals we find agreement in the number of limbs, in the general arrangement of the different parts and organs in the internal structure, the osseous, nervous, muscular, and circulatory systems, in the five senses and in the functional offices of the working parts of the system, as the stomach, heart, lungs, liver, kidneys, brain, mammary and other glands, &c. And if we make the comparison with the Catarhine apes the resemblance is seen to be still closer and the agreement of part with part and function with function to descend to greater minutiæ.

Professor Huxley has in the clearest manner shown the anatomical points of resemblance and the points of difference between the gorilla and man. In his book, "Man's Place in Nature" (page 87) we find the actual measurements of a gorilla as follows: spine, 27 inches from upper edge of the atlas to lower end of sacrum; arm, without the hand, 31½ inches; leg, without the foot, 26½ inches; hand, 9¾ inches long; foot, 11¼ inches.

The following table shows the proportionate length of limbs, calling the spinal column 100:

	SPINE	ARM	LEG	HAND	FOOT.
Gorilla	100	115	96	36	41
Bosjesman, man	100	78	110	26	32
Bosjesman, woman	100	83	120	26	32
European man	100	80	117	26	35
Adult Chimpanzee, ape	100	96	90	43	39
Orang Outang, ape	100	122	88	48	52
Gibbon (Hylobates), ape	100	173	133	50	45
Indri (Lemurine, ape)	100	61	100	30	35

The foregoing table shows a considerable difference in the proportions of limbs between the highest ape, gorilla, and the lowest man, Bosjesman. But it also shows great differences between the gorilla and his brother apes. Thus the arm of the gibbon is as much longer than that of the gorilla, as the gorilla's is longer than man's, and the gibbon's leg is as much longer than the man's as the man's is longer than the gorilla's.

Again, the number of vertebræ in the human backbone is usually 29, not counting the 3 or 4 bones of the coccyx or rudimentary tail. These bones are divided into 7 cervical or neck bones, 12 dorsal or rib bones, 5 lumbar bones without ribs, and 5 united into one called the sacrum. The gorilla has the coccyx or tail bone same as man. His cervical and dorsal vertebræ together make 19, same as in man, but the gorilla has always one more and sometimes two more pairs of ribs than the usual 12 pair in man, the extra ones attached to lumbar vertebræ leaving the lumbar vertebræ less in number than in man. Occasionally in man the number of ribs varies from 12 pairs, there being sometimes 13 ribs and 4 lumbar vertebræ. Once 11 ribs and 6 lumbar vertebræ, and often more than 6 lumbar vertebræ, are said to have been observed. In this matter, as in the case of the lengths of limbs, the gorilla differs as much from his brother apes as from man. One orang-utan skeleton is observed to have 12 dorsal and 5 lumbar vertebræ same as man, and the same was observed in a gibbon. Among the lower apes some have 12 dorsal and 6 or 7 lumbar; some have 14 dorsal and 8 lumbar and some have 15 dorsal and 9 lumbar vertebræ.

Again comparison is made between the gorilla, the gibbon and man in the matter of the broad pelvic bones that support the viscera, showing that those of the gorilla, although smaller and less developed than man's, are more like his than they are like those of the gibbon.

Comparative Table of Vertebræ.

		No. neck vertebræ.	Dorsal vertebræ.	Lumbar vertebræ.	Cross or sacral.	Tail vertebræ.	Total
Tailless.	Man	7	12	5	5	4	33
	Orang	7	12	5	4	5	33
	Gibbon	7	13	5	4	3	32
	Gorilla	7	13	4	4	5	33
	Chimpanzee	7	14	4	4	5	34
With Tails.	Mandrill (Mormon Choras)	7	13	6	3	5	34
	Drill (Mormon Leucophæus)	7	12	7	3	8	37
	Rhesus (Innuus rhesus)	7	12	7	2	18	46
	Sphinx (Papio sphinx)	7	13	6	3	24	53
	Simpai (Semnopithecus Melus)	7	12	7	3	31	60

Next compare brains and skull capacity. The largest human skull observed by Morton of Philadelphia, had a capacity of 114 cubic inches; the smallest observed by anybody had 62 inches capacity. The capacity of the gorilla's skull ranges from 24 to 34½ inches. Thus in cranial capacity there is greater difference amongst men than between the lowest man and the highest ape. It is also stated that the lower apes fall below the gorilla in cranial capacity almost as much relatively as he falls below man.

In the structure of the brain with the medulla oblongata; cerebellum; the hemispheres of the cerebrum each with its anterior middle and posterior lobes; the lateral ventricle, or cavity, with its anterior, descending and posterior prongs or "cornua", and its hippocampus major and hippocampus minor; and the "corpus callosum"; the man and ape are alike in kind though of course not identical in degree. In possessing the posterior lobes of the cerebrum with the posterior cornu of the lateral ventricle and the hippocampus minor man and the apes are alone, as these parts of the brain are not possessed to any considerable degree by any other animals.

Even that part of the brain to which the faculty of speech is due, viz: the insula or Island of Reil, is common to man and the ape tribes and is to only a small extent developed in some of the lower mammals. (The whole subject of the brain and its functions is quite fully discussed further on.)

If we look for an anatomical feature peculiar to man and eminently distinctive, we shall not find it in the brain, but at the opposite extremity. Those gracefully rounded prominences on which we sit, composed of a thick layer of areolar tissue and scientifically named the nates, are not possessed by any ape or other mammal. A dog or a monkey may squat but man alone sits, for he alone is built for sitting.

There are only two muscles in man not found in any ape. One of these is the "extensor primi internodii" of the thumb, and is used to move the thumb backward and outward, the other is the "peroneus tertius" of the foot, which bends the foot upward and turns inward the outer edge. In the absence of these muscles the same movements are performed by others.

The uvula, a backward appendix of the veil of the palate, is also common to man and ape and shared by no other mammals.

It is a curious fact that the trend or direction of the hair growing on the human forearm is upward toward the elbow while that of the upper arm and of the leg is downward. This peculiarity is shared by the great apes and by most of the lower monkeys, but not by the quadrupedal mammals. Scales, feathers and hair are appendages of the skin, and differentiated from it as protection from contusion, cold or wet. The apes being mostly erect and having a habit of protecting their young, and their own heads with their hands during rain, the arrangement of the hair above noted is best for shedding the rain.

One other point of resemblance is to be noted. In natural history the apes and monkeys have been classified as "Quadrumana" or four-handed. As the rest of the mamalia except man are four-footed, it would seem to be an extraordinary break in the natural order to leap from all feet to all hands. But Prof. Huxley has shown that no such

leap has been taken. There is a difference in structure between the human hand and human foot both in the bones and in the muscles. In the bones the chief difference is between those connecting the hand and foot with the arm and leg respectively. The "carpus," which is the part of the hand connected to the radius bone of the fore-arm, is composed of eight bones in two rows of four each, the upper four being joined to the radius and the lower four to the metacarpus or the five bones leading through the palm to the fingers and thumb.

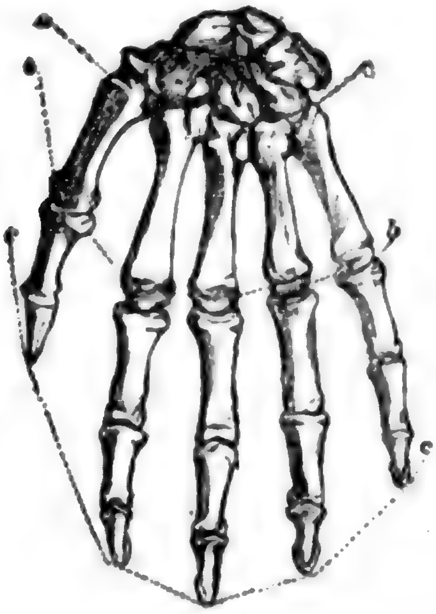

FIG 1.

FIG. 1.—Human hand. Above the line *a* are the eight bones of the carpus or wrist. From *a* to *b* are the five metacarpal or hand bones. From *b* to *c* are the finger bones or digits, each finger containing three sections or *phalanges*, and the thumb two. Compare with hand of gorilla the bones of which are the same as in man, same with the chimpanzee, while the carpus of orang and most other apes has nine bones instead of eight.

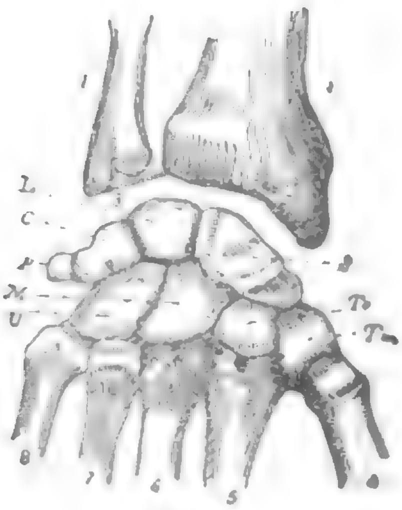

FIG. 2.

FIG. 2.—Carpus or wristbones.
1. Ulna.
2. Radius.
4. Metacarpal of Thumb.
8. " " Little finger.
S. Scaphoid.
L. Lunare (Semilunar).
C. Cuneiform.
P. Pisiform.
Tm. Trapezium.
Ts. Trapezoides.
M. Magnum.
U. Unciform.

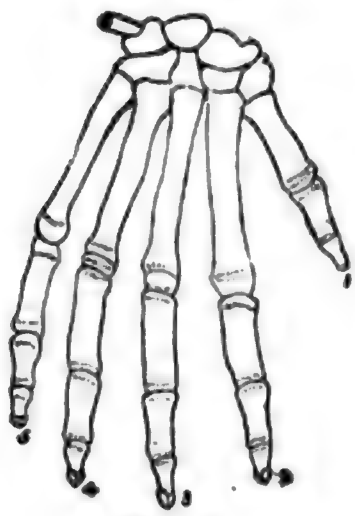

FIG. 3.
HAND OF GORILLA, showing same bones as fig. 2.

The "tarsus" of the foot joins it to the tibia bone of the leg and corresponds with the carpus of the hand. It is composed of seven bones, however, instead of eight, the lower four of which connect with the five bones called the *metatarsus* which lead down through the foot to the five toes; of the other three, one projects backward to form the heel (os calcis), another (the scaphoid) is forward of this, connecting with the lower four of the tarsal bones, while the third (the astragalus) is between and over these two, and resting upon them, it supports the tibia of the leg. The lower bones of hand and foot are alike in number and kind, differing only in proportional lengths and in the flexibility of some of the joints.

There is also a difference between the hand and foot in the arrangement of some of the muscles. Thus there are three flexor and three extensor muscles reaching from the hand up into the fore-arm. In the foot there are likewise three principal flexor and three extensor muscles. Two of each go from the toes up into the leg, but the third one of each is short, extending from the toes only to the sole and back part of the foot. Another great muscle of the foot called the "peronœus longus" passes from the root of the first metatarsal—bone connecting with big toe—up to the outer side of the leg bone—fibula. It is pecular to the foot, having no counterpart in the hand.

Now in the gorilla the same peculiarities of bone and muscle (except as stated above) are observed in the "hind hand," so called, as are to be found in the human foot. The tarsal bones are seven instead of eight, as they are in his hand, and man's, and they are arranged in practically the same way as in the man's foot. He also has the "peronœus longus" muscle and the short flexor and extensor in this "hind hand" but not in the front one. In short, so far as structure goes, he has two feet if a man has and his two front hands are also as true hands as a man's are. It is true there is considerable difference made in the uses

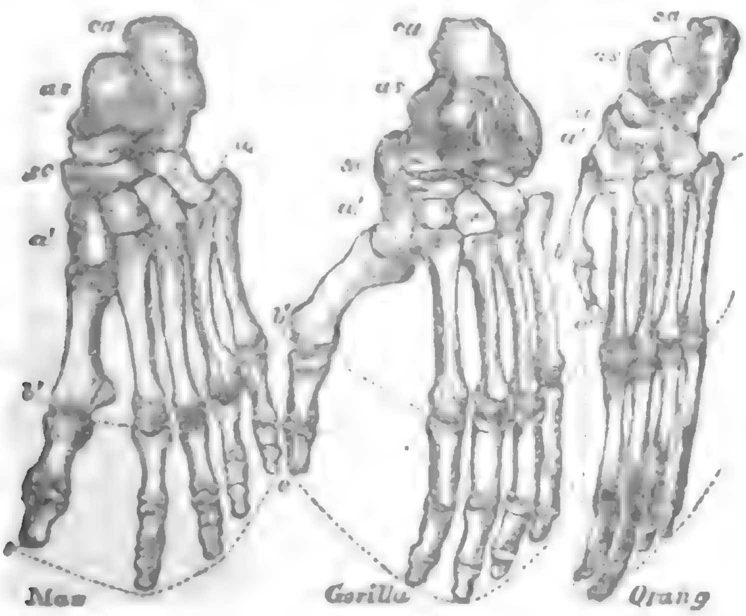

FIG. 4.—Foot of Man.
FIG. 5.—Foot of Gorilla.
FIG. 6.—Foot of Orang.

In each fig. above the line *a*—are the bones of the tarsus, seven in number. *c a*—calcis or heel bone. *a s*—astragalus, which supports the tibia or leg bone. *s c*—scaphoid.
The four bones which articulate with the metatarsals are, beginning at the one next the great toe: the cuboid, the *internal*, *middle*, and *external* cuneiform bones.

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to which the gorilla's foot and the man's foot are put. The gorilla's great toe is more flexible than the man's and he uses it very like a thumb. But the human great toe has not unfrequently been used in the same way. I once saw a man who could do many things, such as beating a drum, whittling with a knife, cutting paper or cloth with scissors, &c., holding the instruments or articles with his great toes as

with thumbs. He could also write an excellent *hand* in the same way.

In the structure of the feet and hands there is a rapid divergence from the gorilla as we go down the scale of the lower apes. Thus the carpus of the orang has nine bones instead of eight as in man and the gorilla. Its foot is wanting an important flexor tendon to its great toe; and the bones of the foot generally depart greatly from the shape and proportions of the same parts in the gorilla, the difference on the whole being considerably greater than that between the gorilla and man.

All the other apes and monkeys show variations of one sort or another in hand and foot, but in no case does the foot lose its typical characteristics; namely, the short flexor, short extensor and "peronœus longus" muscles and the peculiarly pedal arrangement of the tarsal bones. Thus it appears that the ape is wanting in what was supposed to be sufficiently characteristic of him to give name to his order. He is *not* Quadrumanous but Bimanous and Bipedal.

Now this close and minute resemblance between man and the anthropoid apes is something more than accidental. Unlike causes might produce like effects where the effects are single or simple, but where the effects to be compared are complicated, and the comparison tallies in a thousand minute points, we cannot avoid the conclusion that they are produced by the same general causes. In fact, the resemblance is of the same nature as that which obtains between men and compels us to admit their common brotherhood.

By the same process as that pursued above, comparisons could be instituted between the apes and other and lower orders of Mammalia, by which it could be shown that the resemblances between them are more remarkable than the differences. And this sort of comparison could be pursued between the lower mammals and the birds and reptiles, between these again and the fishes, between these and the mollusks, and so on until the comparisons should cover the whole of animated nature—and the same conclusion would finally be reached, that all animals must have come into being by the operation of the same causes.

The theory of evolution is an attempt to show that these causes, whatever they are, have acted and continue to act persistently and everywhere; and that their effect is to develop forms more complicated from those less complicated, these from the still less complicated, and finally those but little complicated from the simple. According to this theory, the close resemblances between the different animals argues a common ancestry and a blood relationship, and the closer the resemblance the nearer the relationship. The nearer the relationship, the more recently, in point of time, has the divergence in stock and blood taken place. We sometimes say of two men "they are enough alike to be brothers." If they are brothers they diverged from each other at the beginning of the

present generation. If they prove to be only first cousins the divergence took place two generations ago. As between a German and a Scandinavian the divergence may have taken place from 100 to 500 generations ago; as between a Frenchman and a Chinaman 10 or 20 times as long ago. As between the man and the ape; the ape and the carnivore; the carnivore and the marsupial; the marsupial and the monotreme; the monotreme and the amphibian; the amphibian and the fishes; the fishes and the tunicate; the tunicate and the worm; the worm and the zoophyte; the zoophyte and the protozoan—the periods when they diverged from each other to become the ancestors of the present races, must be reckoned the first by myriads of ages, and the last by those enormous geological epochs and cycles that bewilder and overpower the imagination by their vastness.

CHAPTER III.

EMBRYOLOGY.

Among the phenomena that tend to prove the common origin and blood relationship, the most striking are those concerned in the prenatal development of the individual. Every animal, including every man, begins existence as a nucleated cell, or, as it might be called, a nucleated globule of protoplasm. These nucleated cells are extremely minute, a common size being about the 1-120 of an inch in diameter. They consist of a bit of protoplasm in which, but not usually in the center, is the nucleus. In this nucleus is a still more minute dark spot called the nucleolus or germ spot. Protoplasm is composed of four elementary substances: oxygen, hydrogen, nitrogen and carbon. These form the binary compounds, carbonic acid, water, ammonia, from which the protoplasm of plants is formed.

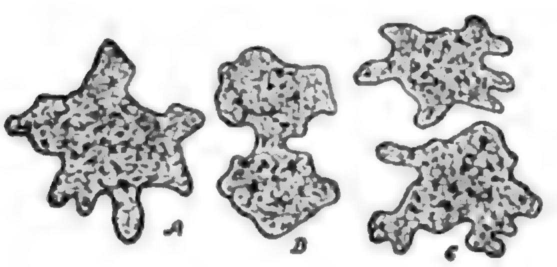


FIG. 7.—Moneron (Protamœba) in act of reproduction.
A.—The whole moneron—which moves like the amœba by expanding and contracting its jelly like substance.
B.—The same partly pinched in two.
C.—The business accomplished and two new ones formed from the old one.

FIG. 7.

The higher animals cannot live on carbonic acid, water and ammonia in their simple condition, although nothing more than these enter into the composition of many of the simpler forms of animal life, and they contain the chief elements required for all forms. But from the plants is obtained the protoplasm from which animal cells are formed. The simplest animals, the protozoa, consist of only one cell. This cell grows in size by absorbing protoplasm from some vegetable matter, and when it reaches maturity it divides into two parts, each part becoming a

new animal composed of a single cell with its nucleus. All animals of every grade are composed almost entirely of nucleated cells, and the most of these cells have the same mode of growth, and increase in number in the same manner as the protozoan.

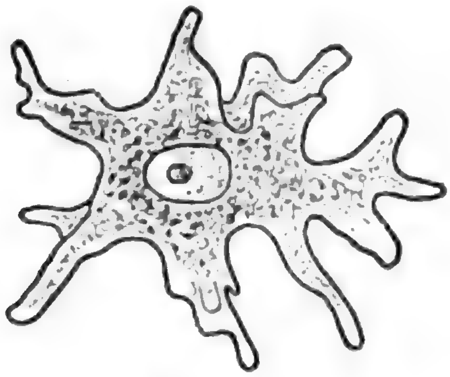


FIG. 8.

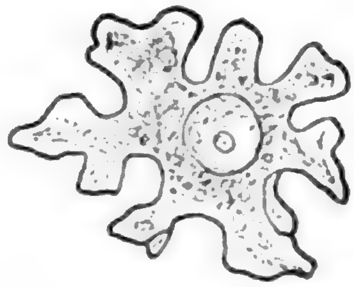


FIG. 9.

FIG. 8.—Amœba much enlarged—"processes" extended as in the act of creeping, nucleus and nucleolus in center.
FIG. 9.—Egg cell of chalk sponge—(Olynthus). It moves about within the sponge and is in all respects like the amœba.—(Haeckel.)

The cells of all the higher grades of animals are differentiated in various ways and are not homogeneous as they are in the case of the lowest animals. Thus, one class of cells composes the skin, another class the bone, another the blood, another the nerves, another the reproductive eggs, &c. These are all similar in their fundamental forms and chemical composition, and yet they are devoted to different ends and functions.

In the protozoan, the single cell is by turns a stomach, a locomotive apparatus, and an egg. In the higher animals only one set of cells act as eggs, while the functions of locomotion, digestion, &c., are performed by organs composed of other classes of cells. The growth of the eggs and the subsequent development of the embryo, have been closely watched, and comparisons have been made, of the mode of this growth amongst all classes of animals. The comparison between man and the other mammals, shows that the same principles, with certain progressive differences of detail, govern the development of the embryo throughout the whole class, and that the difference in the detail of the development is only such as might be expected to occur in view of the different conditions of the lives of the parent animals.

There is no distinction or differentiation of sexes among the protozoans, and some other grades of simple animals, but each animal unites the sexual qualities of both sexes in its one cell amongst the other multifarious qualities of that cell. But in all except the lowest animals (and plants too) the male and female principles are differentiated and one set of cells is set apart for the embodiment of the male principle, and another for the female. And before the embryo can be formed, a male and a female cell must coalesce and the two unite their protoplasm

into one cell. The union of these two cells is called the act of fertilization or impregnation. The female egg cell, or ovum, in mammals, is globular and is surrounded by a covering of transparent matter called the zona pellucida, or vitelline membrane, on the outside of which is deposited a coating of mucous albuminous matter. (These two subsequently amalgamate into one membrane called the *prochorion*, and this afterwards disappears and is replaced by the *chorion.*) The interior part of this cell is filled with protoplasm enveloping the nucleus or germ.

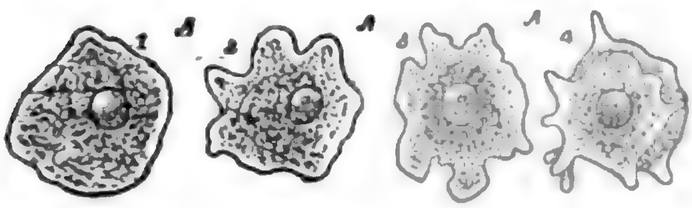


FIG. 10.—Primitive egg cell of chalk sponge performing amœboid movements. Four consecutive positions.

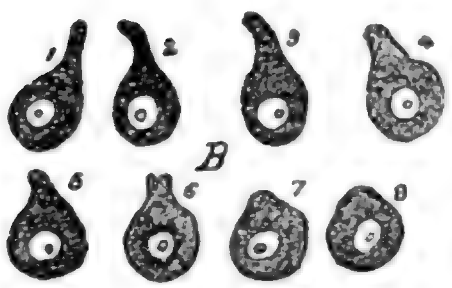
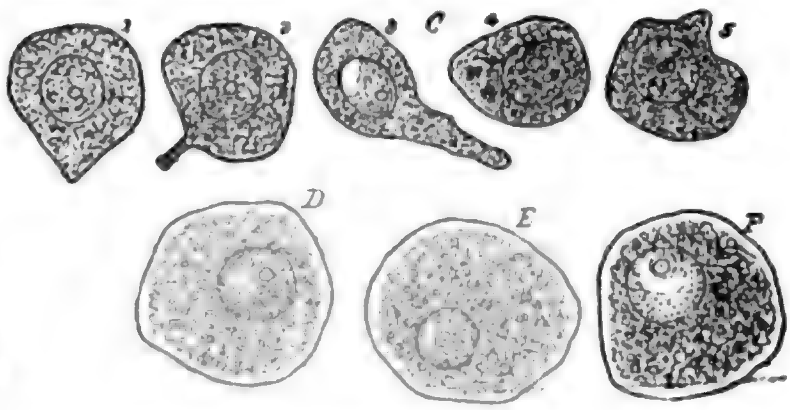


FIG 11.
FIG. 11.—B.-Primitive egg cell of Hermit Crab, in 8 positions assumed by itself.



FIGS. 12 & 13.

FIG. 12.—C.—Primitive egg cell of cat, in 5 positions.
FIG. 13.—D.—Primitive egg of trout. E.—Primitive egg of hen. F.—Primitive egg of man.

All the ova or egg cells of mammals, including those of man, are substantially alike in size, shape, structure, and chemical composition.

The male cell or *spermatozoon*, as it is called, is much smaller than the female cell. But it is of the same force value and the same chemical equivalence. It is somewhat oval or elongated, and from one end there projects a filament or tail of protoplasm. This tail moves, or vibrates, with the restlessness and force characteristic of and innate in protoplasm, and in consequence of its peculiar shape this vibration causes a progressive movement to the cell exactly like swimming. It is this circumstance that caused the first observers to think it was a complete animal in itself and to give it the name spermatozoon (or seed animal).

When the spermatozoon and ovum are brought into contact with each other, the former, under the impulse of a powerful attraction, penetrates the cell walls of the latter, the two protoplasms are thoroughly mingled and the two nuclei coalesce and re-form into a new nuclus or germ spot.

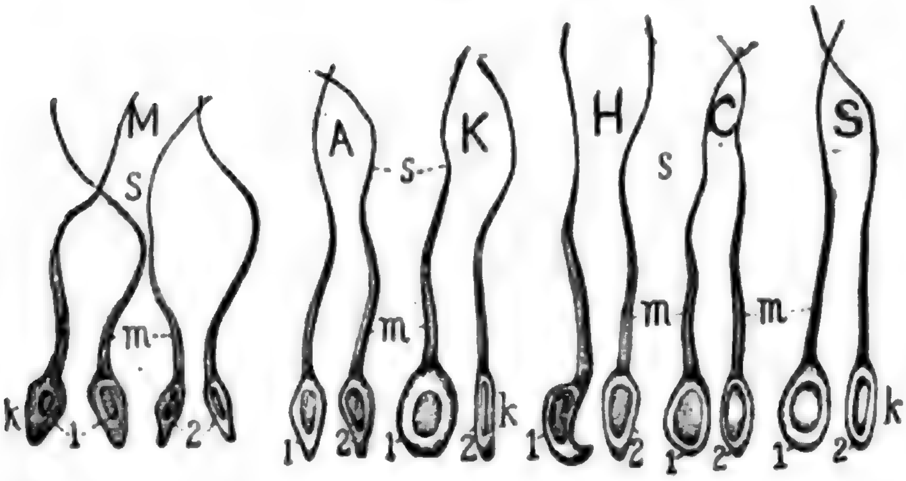


Fig. 14.—Sperm cells (male cells).

M.—Human.
A.—Ape.
K.—Rabbit.
H.—Mouse.
C.—Dog.
S.—Pig.

1.—Broad side of cells.
2.—Edge of cells.
k.—Head.
m.—Central protoplasm.
s.—Tail.

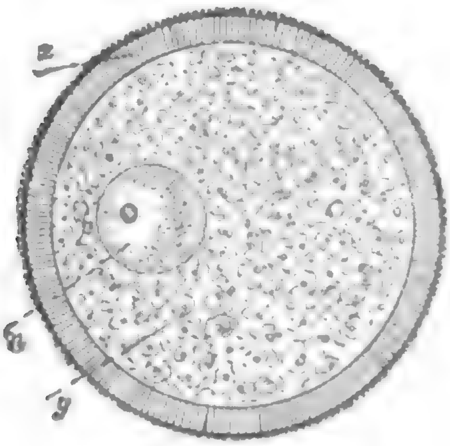


Fig. 15.

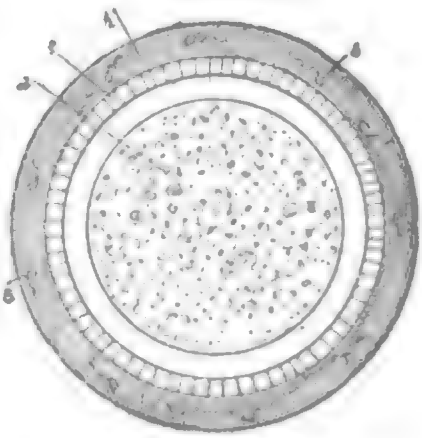


Fig. 16

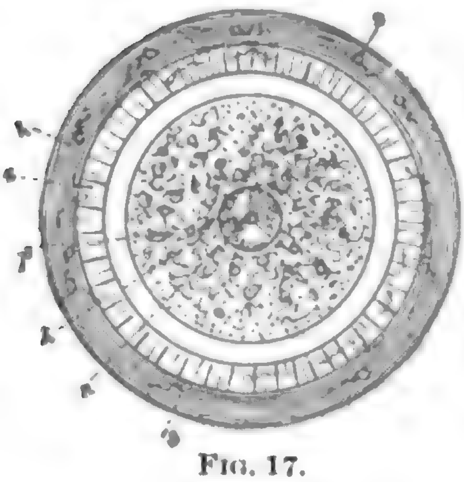


Fig. 17.

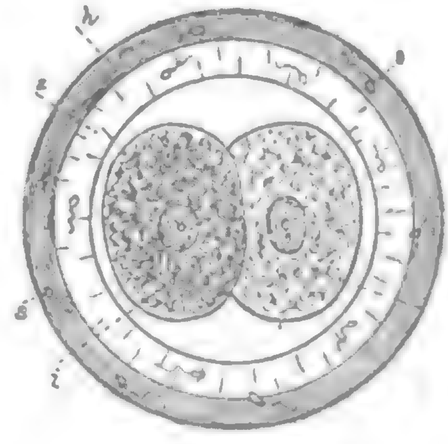


Fig. 18.

Fig. 15.—Human egg not impregnated. *z.*—Zona pellucida or egg membrane cover full of pores, through which the sperm cells penetrate. *y.*—Central part of egg full of nutritive protoplasm. *n.*—Nucleus or germ vesicle within which is seen the nucleolus or germ spot.

Fig. 16.—Fertilized egg cell of mammal (rabbit). Germ vesicle or nucleus has disappeared. Outside membrane is modified, a mucous albuminous layer (*h*) being deposited on the outside of (*z*) zona pellucida. *d.*—Inside yelk or protoplasm. *s.*—Supernumerary disappointed sperm cells.

Fig. 17.—Parent cell (cytula) of rabbit, after the formation of the nucleus (*k*) and nucleolus (*n*).

Fig. 18.—First cleavage of the foregoing into two cells. *e.*—Bright cell, mother of the future skin layer. *i.*—Dark cell, mother of the future intestinal layer. *s.*—Dead sperm cells.

Up to this point, there is no difference in the principles of the formation of the parent egg amongst all the animals above the protozoans—except in the case of certain insects, such as plant-lice, &c., which produce in a line of females for a number of generations during a summer without the help of the male principle, a process that is called Parthenogenesis or "virgin production"*. With these we have nothing to do for the present.

The male and female cells that form the parent cell, as above described, are in many of the animals all carried in one individual, and such animals are called Hermaphrodite. Some of the very simple polypes and sponges, and also many worms, leeches and snails, and the ascidians, &c., are all hermaphrodite. In the case of the lowest vertebrate, the little fish, amphioxus, or lancelet, the two kinds of eggs are carried by separate individuals, the male carrying the male cells, or spermatozoa, and the female the egg cells or ova. It is significant that there is no other difference between the male and female lancelet than that of the separation of the two kinds of cells; all the other organs of the two are precisely alike.

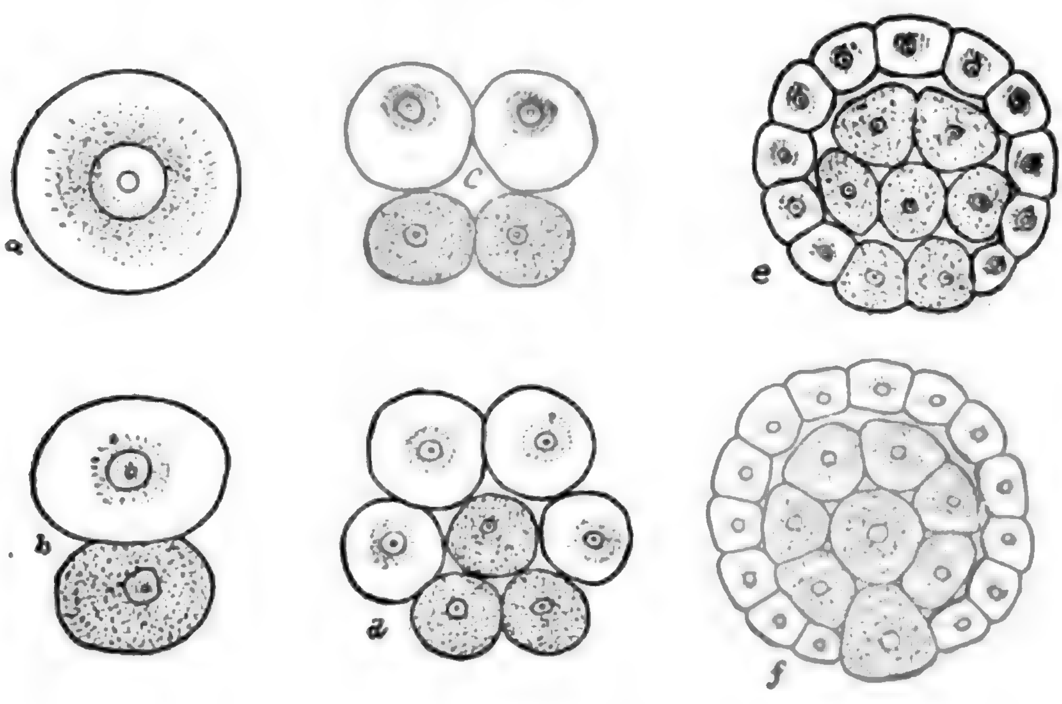


FIG. 19.

FIG. 19.—Egg cleavage and gastrulation of human egg. *a.*—Impregnated parent cell—*Cytula.* *b.*—First cleavage into a large bright cell, the mother of the exoderm, and a smaller dark one, mother of the entoderm. *c.*—Cleavage into 4 cells. *d.*—Beginning of the inversion by which the dark cells are unclosed by the bright ones. *e.*—The process further advanced. *f.*—Hood gastrula formed.—(Hæckel.)

Now to return to the impregnated egg, we will trace its development as it takes place with the mammals, the class of the vertebrate subkingdom to which man belongs.

After the impregnation a new nucleus is formed, as above stated, and

* This is where one impregnation descends from mother to daughter through several generations before it wears out.

takes its position in the middle of the parent egg. Very soon this nucleus separates into two parts which retreat from each other a little way, and soon the rest of the egg, the protoplasm, also divides into two parts, each part forming around one of the new nuclei so that instead of one cell there are now two. They are first globular, then oval in shape, and one is a trifle larger, brighter, and harder, than the other. These two cells now divide again, each one making two. These all again divide, and this process is kept up, each cell dividing into two. This process is called the cleavage of the egg. But the cells are of two kinds, and unequal in number. Those derived from the harder and brighter of the first two, partake of the nature of it, and as the division of those cells goes on with more activity than in the case of the smaller and darker ones, when the total number 96 is reached, 64 of them are of the first kind and 32 of the second. The whole mass is in the shape of a ball, the 32 dark cells being in the middle and the 64 brighter ones forming the cover of the ball. At this stage, the embryo is called a hood gastrula (or amphigastrula). (The name gastrula means "little stomach," or "little gastræa." Gastræa being a name applied to the primitive intestinal animals, or first animals having stomachs. "Hood" alludes to the shape. "Amphigastrula" also alludes to the shape, "amphi" meaning—enveloping, or surrounding.)

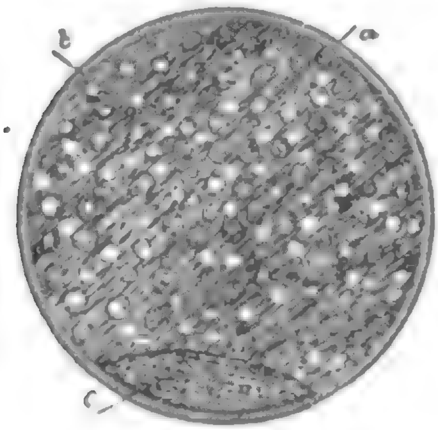


FIG. 20.

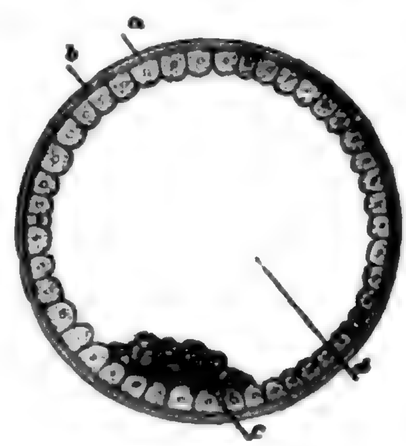


FIG. 21.

FIG. 20.—Germ vesicle of mammal (rabbit) in the stage succeeding gastrulation. *a.*—External egg membrane, chorion. *b.*—Skin layer (exoderm). *c.*—Heap of dark cells forming the entoderm.

FIG. 21.—A section of the above. *d.*—Hollow space within the germ vesicle.—(Hæckel.)

This name is given to distinguish this form of the development of the egg from three other forms which prevail amongst different types of animals.

The process of cleavage and the formation (in the mammals) of the gastrula, as above, takes place, it is said, in the oviduct of the female on the way from the ovary glands to the uterus. The parent egg, now gastrula, moves into the uterus, and at about the same time the process of segmentation continues to go on till it becomes an expanded globe, the outer cells in a single layer forming the shell as before, and the

darker internal cells now collecting first into a mass and then into a plate or round disc on one side of the hollow interior. This spot is called the germ area or germ disc, and when fully formed it consists of the two single layers of cells, the outer or *exoderm* cells which go clear round the globe, and the small inner layer or *entoderm*, covering only a fraction of the inner circumference of the globe. The place inside the globe not occupied by the entoderm cells becomes filled with a bright, transparent liquid. This process has all gone on within the original egg covering or zona pellucida with its mucous coating, before mentioned, and to which the name prochorion is given. This prochorion now increases in size more rapidly than the enclosed egg, thus leaving a space between the two which becomes filled with fluid. On the outside of the prochorion there are developed numerous protuberances or sprouts which mark the places where afterwards the tufted processes or villi appear which are to connect the chorion with the uterus.

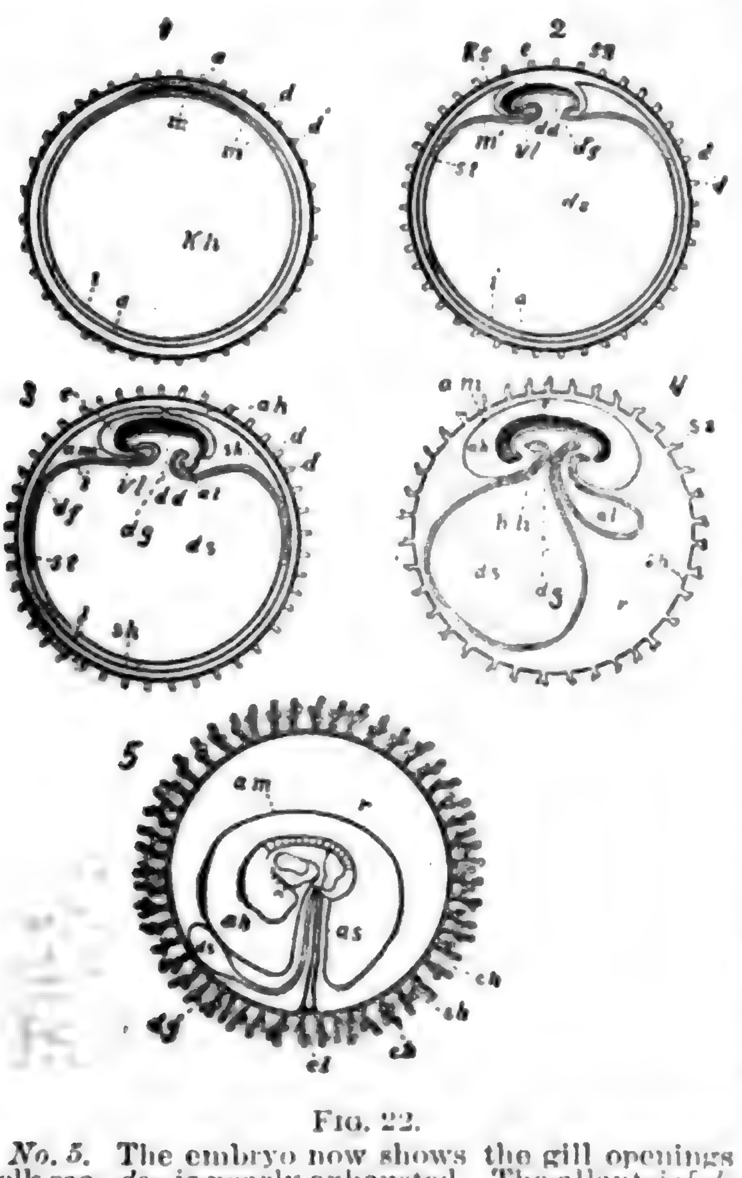


FIG. 22.

FIG. 22.—Diagrams of development of mammal embryo and its membranes. Longitudinal vertical section.

No. 1. *a.*—Outer germ layer. *i.*—Inner germ layer. *m.*—Middle germ layer, developed from the other two. *kh.*—Intestinal germ vesicle or yelk. *d.*—Prochorion with its tufts *d*.

No. 2. *e.*—The embryo beginning to be separated from the germ vesicle *ds* by the constriction *dg*. *ks* and *ss.*—Head and tail folds of the outer germ layer which are beginning the formation of the amnion. *dg.*—Yelk duct or opening by which the contents of *ds* are conveyed to the growing embryo. *dd.*—Intestinal glandular layer—forming intestinal canal. *vl.*—Region of the heart.

No. 3. The head and tail folds of the amnion have approached till they touch, leaving only a thin partition between the spaces on each side. *am.* Amnion sac. *sh.*—Serous membrane. *df.*—Intestinal fibrous layer. *ah.*—Amnion cavity. *al.*—Allantois forming at hind end of intestine.

No. 4. The amnion cavity-*ah*-has enlarged and the serous membrane—*sh*—has been pressed outward and consolidated with the prochorion. *sz.*—Tufts of same. *r.*—Space between the amnion and chorion filled with fluid. The embryo has grown and so has its waste basket, the allantois—*al*—both at the expense of the yelk-sac—*ds*—which has correspondingly decreased.

No. 5. The embryo now shows the gill openings and the rudimentary limbs. The yelk sac—*ds*—is nearly exhausted. The allantois [*el*—in this no.] has reached the chorion and is being attached to it, this part of the latter subsequently becoming the placenta while the stem of the allantois is shriveled up into a hollow cord, which becomes the umbilical cord having that part of the amnion membrane marked —*as*—as its "amnion sheath."—(Kolliker.)

Now to return to development of the egg.

It consisted (when we left it) of a single layer of cells surrounding a

globe of liquid and forming its shell, on the interior of which shell another layer of cells had formed itself, covering, however, but a small part of the whole of the interior surface of the outer layer. The spot thus formed is called the germ area or germ disc. The outer layer of cells or shell is called the *exoderm* and the inner circular spot is called the *entoderm*; the two terms meaning, respectively, the "outer skin" and the "inner skin." These two layers are designated as the "primary germ layers," because the whole development of the animal proceeds from them. The outside one, or exoderm, is also called the *skin layer* and the *animal layer*.

The inside one, or entoderm, is also called the *intestinal layer*, and the *vegetative layer*. There is now formed between the entoderm and the exoderm a third layer called the *mesoderm* or "middle skin." This is somewhat smaller in area than the entoderm. It is supposed to be formed by cells from both the entoderm and exoderm. At any rate it soon becomes *two* layers instead of *one*, and the germ area or germ disc now consists of 4 cellular skins which are distinct from one another and could be split apart. They are now called respectively, beginning at the outside,

1. Skin sensory layer or skin stratum.
2. Skin fibrous layer or flesh stratum.
3. Intestinal fibrous layer or vascular stratum.
4. Intestinal glandular layer or mucous stratum.

In the meantime the entoderm has been increasing its area and rapidly extending its cells in a single layer in all directions from the germ disc until it entirely covers the inner surface of the exoderm, so that except at the space called the germ disc, the ball of liquid is covered by a double skin, the original exoderm, and the entoderm.

During the above described formation of the four plates and before the division of the middle one, other important changes are going on.

The germ disc has changed in shape from circular first to an elliptic form, then to an oval, and lastly, to the shape of a shoe sole or a fiddle. That is, the oval has lengthened and the sides remain relatively contracted making it narrower in the middle than at either end, but leaving one end wider than the other. It is now called the *germ shield* on account of its changed form. The middle part of the shield becomes much thicker and the plates become more distinct, especially the first and fourth. The shield arches up in the middle and appears to rise above the central part of the egg. A groove or trench is formed lengthwise through the center of the shield. On each side of this trench the outside layer or skin stratum folds or doubles up and forms a low ridge. These ridges continue to increase in height and incline toward each other until they finally touch each other over the trench where they

coalesce and then the trench becomes a tube. This is called the medullary tube and it afterwards becomes the seat of the spinal cord. It now becomes apparent that the future animal lies on its belly upon the central part of the egg. Its back is the outside or top of the germ shield, the wide end of the germ shield is to be the head and the narrow end the tail. Just under the medullary tube, and running parallel with it and lengthwise of the shield, another long cylindrical body becomes detached from the skin fibrous layer or flesh stratum. This cylinder is the *notochord* or the rudimentary backbone. It occupies the position afterwards occupied by the transverse processes of the backbone, and the oblique processes, when they are formed, reach around and enclose the medullary tube which then becomes the spinal canal. All around the edges of the germ shield the outside skin stratum together with the flesh stratum, now begin to form a ridge by a swelling fold of these two layers. This fold or doubling of these skins continues to rise and reach over the shield from all sides, but more rapidly over the head and tail than the sides; until finally the folds touch each other and coalesce over the back of the shield. (See Fig. 22.)

The edges of doubled membrane, where they meet and touch each other, form partitions which are soon absorbed in such a way as to make the space between the upper and under folds of the skin layer continuous across the shield, and the shield is left in a cavity canopied by two continuous and independent sheets of the original skin layer. This operation, by doubling or folding the skin stratum, causes the part of it on the inside of the cavity to face toward the shield and leaves the rest facing as before in the contrary direction toward the prochorion or original outer shell of the egg. This outward-facing part of the skin layer now moves away from the other part and the space between them is filled with fluid. The outside portion is gradually pressed against the prochorion with which it appears to fuse and so form the permanent chorion. The other inner part of the skin-fold that roofed over the cavity above the germ-shield becomes the *amnion sac.* It becomes filled with fluid and gradually enlarges and distends itself until later it entirely surrounds the embryo.

While this process is going on above the shield, the skin stratum just below the edge of the shield, is becoming constricted or drawn in all around and especially on the sides of the shield, a process which has a tendency to make another tube or cavity on the underside of the shield below the notochord and at the same time to separate the shield, or embryo as we may now call it, together with its covering, the amnion sac, from the lower and larger part of the original egg. This makes a sac of this larger part which is called the yelk sac. The cavity thus formed from which the principal part of the yelk sac is thus partly separated, is

the future cœlom or body cavity. The body is now substantially two tubes, one outside, composed of the skin stratum and flesh stratum with their appurtenances, and inside of this, the other and smaller one composed of the vascular and mucous stratum. The body cavity, the wall of which is the flesh stratum, is the holder of this intestinal tube with all its subsequent derivations of heart and blood vessels, liver, lungs, kidneys, &c.

The fluid contained in the yelk sac is nutritive protoplasm called the yelk, and is being used by the developing embryo to supply the materials for all the changes and growths above enumerated as well as those that follow. The opening or neck between the yelk sac and the cavity of the body is called yelk duct and it remains wide open until it is closed in upon by being surrounded by the swelling amnion sac, and until the bulk of the yelk has been absorbed by the growing embryo.

FIG. 23.

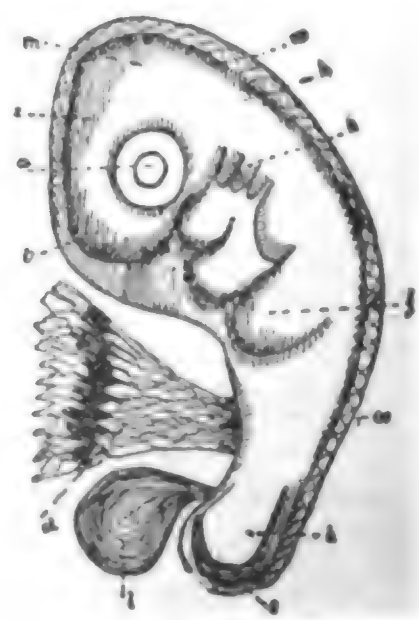


FIG. 24.

FIG. 23.—Human embryo, third week. C.—Chorion with tufts. E. Embryo. Am. Amnion. Al.—Allantois. Y.—Yelk sac.—(Hæckel.)

FIG. 24.—Human embryo, fourth week.

d.—Yelk sac torn off.
b.—Legs, just budding.
m.—Mid-brain.
a.—Eye.
s.—Tail.
l.—Allantois.
v.—Fore-brain.
h.—Hind-brain.
k.—Three gill arches.
w.—Vertebral column. (Krause.)
f.—Arms, just budding.
z.—Twixt-brain.
n.—After-brain.
e.—Heart.

The double membranes that form the yelk sac are the two that we saw were formed from the original entoderm; viz., the vascular stratum and the mucous stratum. The constriction of the skin stratum causes the parts of these layers that remain above the line of the constriction to close up in the shape of a tube within the body cavity. This tube is the rudimentary intestine and is afterward developed into the alimentary canal, stomach, &c. At first it is nothing but a plain tube closed at both ends and opening from its middle part into the yelk sac through

the yelk duct which (latterly) passes through the skin stratum on the belly side of the embryo.

The yelk sac is early furnished with bloodvessels by which its nutriment is taken up and carried into the heart of the embryo. As the development of the embryo advances, this nutriment in the yelk sac is gradually consumed, and another apparatus is substituted in its place for supplying the necessary nutrition. This is the allantois or sausage. It is to be noted that the original use of the allantois was not to nourish, and in the case of the higher mammals it is simply adapted or modified to suit that end.

The allantois is at first a little pouch or bladder which is developed near the rear end of the intestinal tube. It is formed as a continuation or rather branch or diverticulum of that tube and is composed of the same layers that form the tube and yelk sac. The first office of the allantois is that of a urinary bladder, and it receives the urine from the growing embryo. It protrudes from the intestinal tube through the wall of the body cavity much as the yelk sac does, and as the yelk sac decreases in size the allantois gains. It is early supplied with blood vessels. As it grows it pushes its way until its end comes into contact with the wall of the chorion. See Fig. 22—No. 5, cl.

The chorion has by this time connected itself by means of its villi or tufts with the inner wall of the uterus. When the membrane of the allantois reaches the chorion, the blood vessels of the allantois penetrate through into the hollow tufts on the outside of the chorion. This brings the blood of the embryo into close proximity to the blood of the mother, and enables the latter to supply its elaborated nutriment to the former. The two bloods do not, however, flow directly into each other, but that of the embryo absorbs nutrition from the mother's blood through the walls of the villi or tufts.

The junction of the allantois to the chorion covers a flat area circular in the human being, and when the embryo is mature it is a thick cake six or eight inches in diameter. It is called the placenta. The stem of the allantois then shrivels up into a cord a half inch in diameter, and which is finally eighteen or twenty inches long, which is then called the umbilicus. When the yelk sac is exhausted of its nourishment its remains are pinched off from the intestinal tube. After which the belly wall closes over and no trace of the yelk duct is left, either in the outer wall of the body cavity or on the intestinal tube. The point, however, where the umbilicus passes through the wall of the body cavity, leaves its permanent mark in the "navel," because the wall closes up around the cord while it is still in active use.

Now return to the development of other parts which has been going forward at the same time. On the front end of the medullary tube, a

rather long bladder-like swelling takes place, which is the first intimation of a brain. Soon this long bladder brain is partly separated into three parts by two constrictions. These parts are called the "fore-

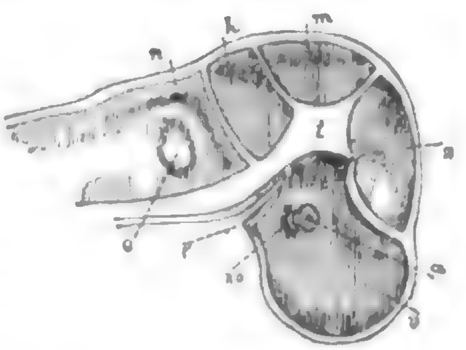


FIG. 25—Primitive skull of human embryo of four weeks—vertical longitudinal section through the middle.
v z m h n—The five sections of the skull cavity occupied by the five brain bladders respectively; viz., the fore-brain, twixt-brain, mid-brain, hind-brain and after-brain.
o.—Ear vesicle.
a.—Eye.
no.—Optic nerve.
p.—Canal of pituitary gland.
t.—Central part of the cranial basis.
(Kölliker.)

brain," "mid-brain," and "hind-brain." A little later and a fourth and a fifth segment of brain bladder is formed by the division of the "fore-brain" and "hind-brain" into two each. There are, then, five brain bladders, the first of which in the human subject, develops into the cerebrum and olfactory lobes, the second into the optic thalamus with the third ventricle, the third into the corpora quadrigemina or optic lobes, the fourth into the cerebellum, and the last into the medulla oblongata or upper enlargement of the spinal cord.

(See chapters on the brain.)

In the meantime the eyes have been started by a pear-shaped vesicle pushing out on each side from the third ventricle of the brain, against the outer skin. These vesicles have each a hollow stalk or stem reaching back to the cavity of the "twixt-brain" bladder of third ventricle. The outer skin is first protruded by the eye vesicle pushing out. It thickens up over the eye vesicle, then an indentation from without is formed in the thickened skin. This deepens into a little cup, the edges of which contract toward each other until they touch, and so form a ball. This is the future lens of the eye. The formation of this lens in this manner has the effect to push in and double back on itself, the front end of the vesicle forming a double skinned cup, fitting the lens. The inside skin of this cup next the lens represents what afterward becomes the retina. The outer layer of the cup (next the brain) represents the pigment membrane which gives the eye its dark color. A fold from the "flesh stratum" now forces its way from below the eye, inside of the skin stratum, and enters between the lens and retina and forms the rudiment of the transparent gelatinous body called the vitreous humor of the eye. A strip of this vitreous body also pushes its way along the underside of the first formed stem or eye stalk, the rudimentary optic nerve. This stalk thereupon first collapses into a double layered semi-cylindrical strap. It then folds itself over the strip of vitreous matter thus forming a new tube, second rudimentary optic nerve, with the vit-

reous matter as a core. This core afterwards becomes the tissue accompanying the central artery of the eye.*

The ear, in the meantime, is developed in connection with the posterior brain bladder—the bladder of the medulla oblongata. The skin opposite this part is first bulged out and thickened. It then becomes indented from without, the indentation increasing till a cup is formed. This cup is then pinched off from the outside skin, sinks back into the head and becomes a sac of the shape of a pear, and is filled with a fluid. It is connected with the brain bladder by a slender pedicle which afterwards becomes the *portio mollis* or auditory nerve. The pear shaped sac is divided into two apartments, the posterior of which is the *utriculus* in which the semi-circular canals are subsequently developed, and the other is the *sacculus* in which are developed later the cochlea, the stairs, &c. These two sacs together constitute the labyrinth of the ear. From the first gill opening, to be described presently, the ear drum and the eustachian tube leading from the drum to the pharynx, are formed. Lastly the external canal or *meatus* from the drum through the skull to the outside, and the ear flap are developed. The formation of the bones in the ear drum is also a late development.

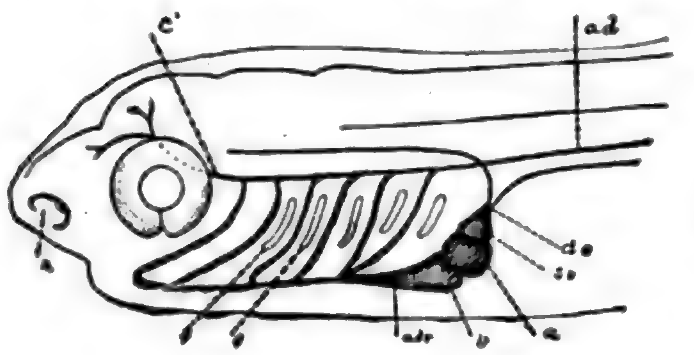


FIG. 26.

FIG. 26.—Head of embryo fish—showing arrangement of gill arteries.
dc.—Junction of front and hind veins.
sv.—Venous sinus—vein receptacle.
a.—Auricle.
v.—Main chamber.
abr.—Stem of the gill arteries.
s.—Gill slits between the arterial arches.
ad.—Aorta—supplying purified blood to the body.
c.—Head artery supplying brain, &c.
n.—Nose groove.
(Gegenbaur.)

Now turn back to the development of the forward part of the body as it lies, belly down, upon the yelk sac. In front of the yelk sac the exoderm, with its skin stratum and flesh stratum, has curved under the medullary tube from each side and coalesced there forming the outer casing of the body. It has, however, left four vertical openings on each side in the skin just under the brain bladders which are called the gill openings. The skin between these openings forms the gill arches. They represent the permanent gills of fish and amphibians. In the mammal embryo they are subsequently diverted and developed into other forms or entirely obliterated. The first gill slit becomes the track of the eustachian tube, tympanum, and meatus, of the ear as before mentioned—leading from the mouth through the drum to the outer opening of the ear.

The first system of arteries includes temporary arterial vessels lying

* See Haeckel's Evolution. 259—2.

on the inner side of the gill arches after the manner that is permanent in the primitive fishes. But afterwards, in all the higher vertebrates, the anterior two of these disappear and the permanent main arteries develop from the posterior three, the lung arteries from the last one.

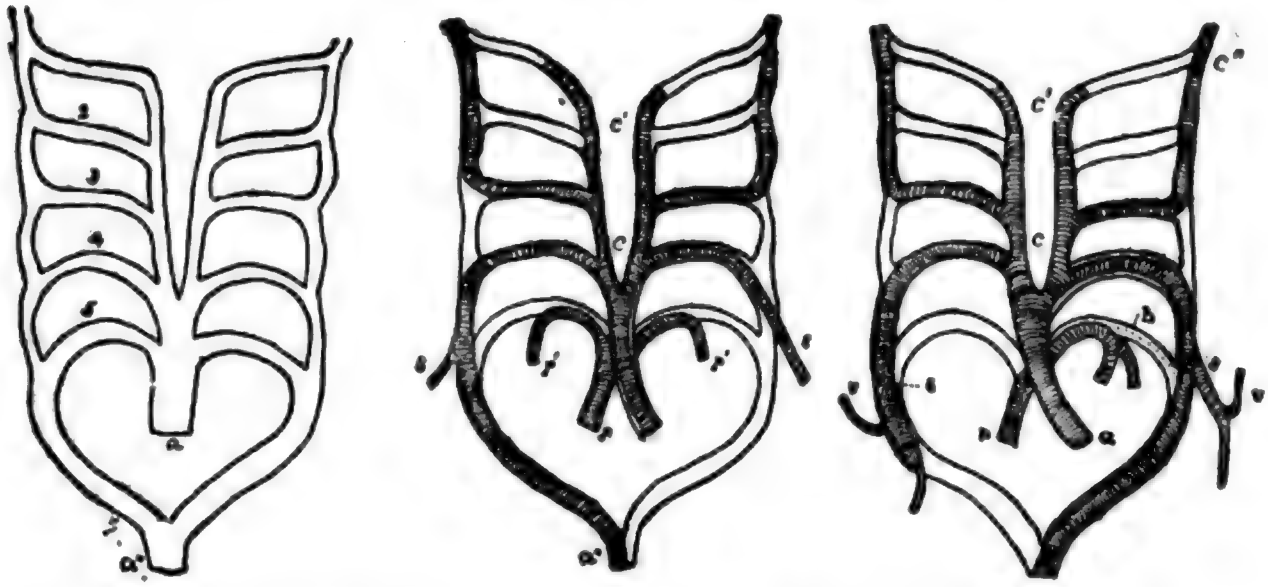


FIG. 27.—The five arterial arches as originally formed in the skulled vertebrates. *a.*—Arterial stalk. *a'*.—Main stem of aorta. *c.*—Head artery (Carotis.)—(Rathke.)
FIG. 28.—The arterial arches as formed in birds—the unshaded parts are rudimentary and disappear—the dark parts remain. *a.*—Arterial stalk. *a'*.—Main stem of aorta. *c.*—Carotis. *p.*—Lung artery. *p'*.—Branches of same. *s.*—Subclavian arteries.—(Rathke)
FIG. 29.—The five arterial arches of mammals. The light parts disappear—letters as in last fig. *v.*—Vertebral artery. *b.*—Botallis duct used by the embryo but afterwards closed.—(Rathke.)

Directly after the formation of the medullary tube, notochord, and intestinal tube, the heart begins to form from the front end of the intestinal tube and in connection with the blood vessel system. The first appearance of a heart is in the form of a straight spindle-shaped organ without a cavity. (The blood vessels also first appear as cords without cavity.) Soon, however, a cavity is developed in it, and it takes a shape approximating that of the letter s. From each end of it two blood vessels proceed. Those in front passing by the first gill arches, one on each side, after the manner that is permanent in adult fishes, unite above the intestine and run thence backward as a single aorta just below the notochord. It soon divides and sends ramifications first all over the germ area and then into the yelk sac. The two vessels from the posterior end of the heart are veins and bring the blood back to the heart. The heart itself next divides into two cavities, an auricle and a ventricle. Leading up from the ventricle is a tube from which the aortal arches spring, and leading into the auricle are the two veins. The auricle has in the rear, on each side, an appendage called the auricular process. This is permanent in the lower fishes, and the whole heart, at this stage, is the heart of an adult fish.

Later, the auricle divides into two chambers, and lastly, the ventricle also divides into two chambers. In the human embryo this stage is reached by the fourth week of embryo life. The lungs, in the mean-

time, have grown from the front end of the intestine just back of the gills. They begin as a single little sac or bladder growing from the underside of the intestine. This divides into two which take their places under and on each side of the intestine. The short connection that at first joined the lung sac to the upper intestine, first lengthens and then divides into two branches, one going to each of the two sacs (after their separation). The upper end of the intestine to which the lung tube is joined, finally develops into the pharynx, and the lung tube differentiates at its upper end into the larynx, and at its lower into the wind pipe, or trachea, while the branches into the lungs are called the bronchial tubes. The development of the lungs keeps pace with that of the heart, so that by the time the heart has become four chambered the lung circulation has become complete and separate from the body circulation.

Very early in the development of the embryo begins the formation of the primitive kidneys, or wolffian bodies, as they are called. The use of the kidneys is to absorb and carry out of the arterial blood excessive quantities of nitrogenous matters and water. The primitive kidneys are supposed to be developed from the skin sensory layer. At first they are a mere string of cells set off just under the outside skin of the back on each side of the rudimentary vertebral column. These strings enlarge and become a pair of tubes reaching from front to rear. During the development of the embryo, these tubes, or kidney ducts, as they are now called, are crowded inward and finally bring up on the inner surface of the body cavity outside of and above the intestine. In the meantime they develop on their inner and under side, a row of short tubular branches. These receive the blood vessels from which the primitive urine is extracted.

The wolffian bodies disappear in the ninth or tenth week in human pregnancy, and their functions are assumed by the permanent kidneys and renal capsules. In the other mammals the wolffian bodies persist for a longer time, and in the fishes and amphibians they are the permanent urinary organs during life.

The posterior end of the kidney tube opens into the rear end of the intestine, which then forms a cloaca, or common receptacle, as in the monotremes, birds, reptiles and fishes. From this cloaca, in the young embryo, the opening is into the *allantois*. The kidney tubes, with their tubular appendages, extend forward to the region of the heart.

From the posterior section of the primitive kidney duct the secondary or permanent kidney ducts originate at an early period. The secondary or permanent kidney duct grows out from the primitive kidney duct near its entrance into the cloaca. It therefore originates from the skin layer, as does the kidney. It grows forward as a tube and gives rise to

a number of small branch tubes similar to those described in connection with the primary kidney duct. The ends of these tubes afterwards receive the permanent coiled arteries that pass the blood in and out of the kidneys. The posterior ends of the kidney ducts remain as canals and become the ureters or tubes for conveying the urine into the bladder. At first, the ureters discharge into the cloaca through the primitive kidney duct, but later, the connection is with the part of the allantois which remains within the body cavity after the closing of the body-wall, and which becomes the permanent urinary bladder. The posterior or lower end only, of the allantois stalk, is used for the bladder, and the remaining part between the bladder and the navel remains shriveled up into a solid cord called the urachus, no longer of any use. The urinary bladder, at first, of course, opens into the intestine where the allantois was joined to the intestine, but later, in the higher mammals, a transverse partition is formed, separating the urinal exit from the body from the intestinal exit.

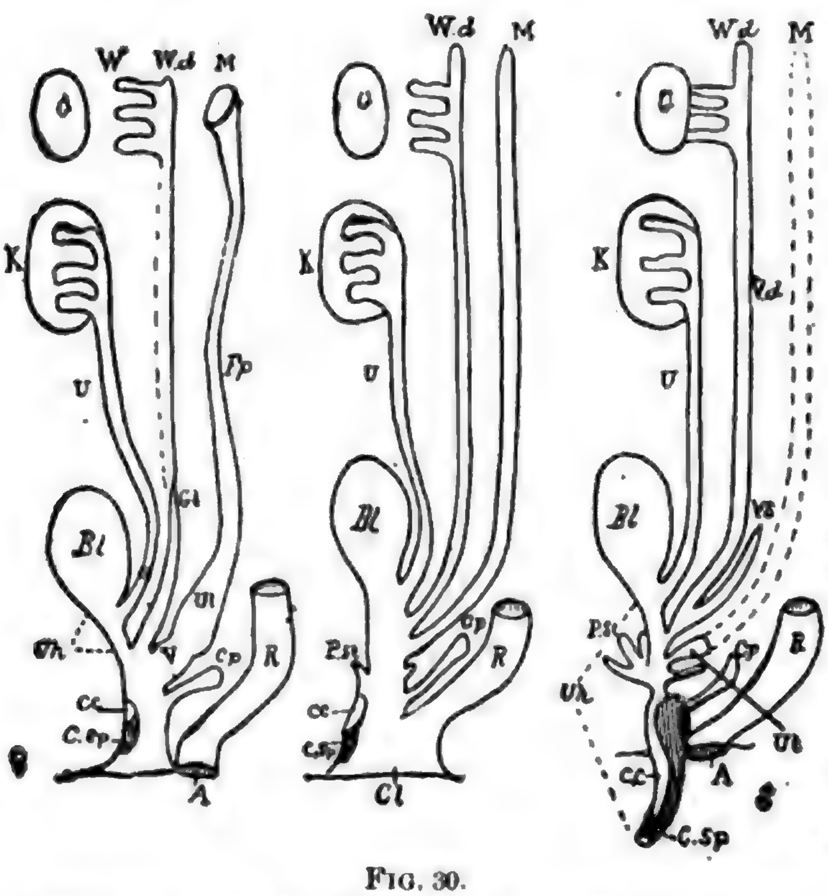


FIG. 30.

FIG. 30.—Diagram of reproductive organs.

Middle fig. is general plan of reproductive organs. Left hand is female, and right is male derivative.

Cl.—Cloaca. R.—Rectum. Bl.—Urinary bladder. U.—Ureter. K.—Kidney. Uh.—Urethra. G.—Genital gland—ovary or testis. W.—Wolffian body. Wd.—Wolffian duct M.—Müllerian duct. Pst.—Prostate gland. Cp.—Cowpers gland. Csp.—Corpus spongiosum. Cc.—Corpus cavernosum. In female. V.—Vagina. Ut.—Uterus. Fp.—Fallopian tube. Gt.—Gaertners duct. W, Wd.—Becomes parovarium. A.—Anus. Cc, Csp.—Clitoris. In the male. Csp, Cc.—Penis. Ut.—Masculine uterus. Vs.—Vesicula seminalis. Vd.—Vas deferens. (Huxley.)

Inside of and a little below the primitive kidneys are formed the germ glands or organs for the production of the egg cells. These glands originate from the boundary line or place of junction of the two primary germ layers, where they originally unite to form the middle layer of the embryo shield, near the place from which the primitive kidneys were originally differentiated. These spots necessarily keep near the kidneys as they are gradually pressed to the body cavity by the formations outside of them.

At an early period of embryonic development, each of the wolffian

bodies, or primitive kidney ducts, puts forth a branch near the point of union with the intestine (or cloaca). This branch runs forward parallel with the kidney duct and terminates near the egg or germ gland. It is called the müllerian duct. This müllerian duct and the wolffian, or primitive kidney duct, are to become the seed ducts to convey the germ cells from the sexual gland.

The sex at this time is not determined, or rather the embryo belongs to both sexes, and the germ gland is, no doubt, a rudimentary hermaphrodite gland. When the sex is determined, (which in the human embryo occurs from the 7th to 10th week) if it is a male the testis is developed at the upward or forward end of the wolffian ducts, the lower ends remaining as sperm ducts, while the whole of the müllerian ducts disappear except a useless rudimentary remnant which receives the name, male uterus.

If the embryo is a female, the ovaries develop from the upper or forward end of the müllerian duct, while the lower end of the müllerian duct widens into a pouch which becomes the uterus. At this stage of the development the female embryo has two uteri, one on each side. Later, the lower ends of the two uteri unite into one, and those parts of the ducts leading from its corners to the ovaries, become the fallopian tubes. The wolffian duct, in the female, is reduced to a useless and functionless rudiment called the parovarium or supplementary ovary.

The position of these organs changes during the development of the embryo. From being in the neighborhood of the kidneys they gradually work their way towards the posterior end of the body. The ovaries of the human female finally stop at or in the small pelvis. The male testes, however, go still further, and passing through the pelvis and the groin canal, bring up in the fold of the outer skin, called the scrotum, quite outside of the body; the scrotum itself consisting of the same parts which in the female become the greater lips of the pudendum.

At the front end of the body, at an early period, a pair of small grooves are formed on the under or front side of the head. These are called the "olfactory grooves." They are simply indentations of the outer skin layer and do not, at first, at all communicate with the internal cavity of the body. Just below these is a like indentation in the outer skin layer, which constantly deepens toward the forward end of the intestinal cavity, until it at last joins and becomes continuous with it. Thus the mouth and nostrils are formed by and lined with the outer skin layer.

Next trace the development of the osseous system.

The notochord, which is the first rudiment of the backbone as already stated, is separated from the skin fibrous layer at a very early period, as

a line of distinct cells running lengthwise of the body and just under the medullary tube. On each side of this notochord another parallel strip of cells is set off from the same skin fibrous layer. These two strips afterward develop the vertebræ, and they are called the primitive vertebral cords or layers. These cords begin to differentiate by breaking up into short segments which represent the future vertebræ. At first they become simply cubical shaped bodies of cartilaginous matter arranged symmetrically on each side of the chorda, and developing progressively from front to rear. The first of these primitive vertebræ formed are the first two pairs of neck vertebræ which appear almost simultaneously. These are followed by the others until all are formed, the number depending upon the species of animal, those of the tail being the last to form. In man the total number of pairs is 33 or 34.

In the front end of the embryo the same middle layer without detaching the primitive vertebræ as in the rear, expands into a thin-walled vesicle which surrounds the brain and becomes afterward cartilaginous or membranous in texture and at last bony. The full bone over the top of the head in the human species is not completed till some months after birth.

The jaws develop from the first or anterior gill arch. The upper jaw comes from a process that starts on each side of the face from the front or anterior part of the gill arch. On the inner side of the gill arch a cartilage is formed which develops the lower jaw. The cavity of the mouth is divided into two, an upper and lower, by a horizontal partition which reaches across from the two side or wing bones of the upper jaw, forming the palate or roof bone of the mouth. The cavities above and below the palate unite at the rear in the pharynx. At the same time a vertical plate is developed dividing the single cavity above the palate into two cavities—the nostrils. The intermaxillary bone is also formed from the upper jaw process. It is a bone wedged in between the two upper maxillary bones. It is permanent in the apes and other mammals and is developed in the human fœtus, but is afterward eliminated and does not exist in the adult man.

The limbs begin as mere buds or knobs, forming from the skin-fibrous layer covered on the outside by the horn plate or skin layer. The front ones appear first. They soon assume (in man and the higher vertebrates) the form of a paddle with a heavy, clumsy blade and a short, thick stem. Next, the front edge of the blade becomes notched or indented with four indentations which subsequently deepen, leaving the projections as digits. The digits are at first connected by a thin, web-like membrane. The embryo is then web-footed, or rather finned. Meantime the stem of the paddle divides into two sections, the upper and lower.

The formation of the bones, muscles, &c., is effected by the differentiation of cells of the skin-fibrous layer.

The embryo big toe in man is thumb like, as it is in the adult ape.

The tail is formed simultaneously with the limbs, but at first, more rapidly, so that in the human and other vertebrate embryo at an early stage it is considerably longer than the hind limbs.

The anal opening is formed the same as the mouth, by the indentation of the skin layer from the outside as a blind sac growing inward until its end comes into contact with the blind end of the intestine when the end walls are absorbed and the two cavities become a continuous one.

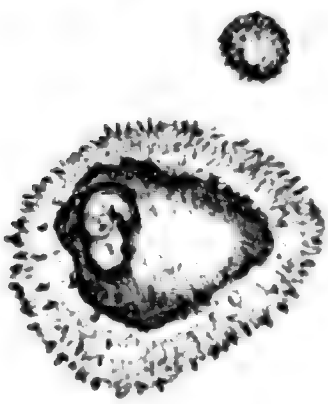


FIG. 31.—The small fig. represents the human egg the 12th or 13th day—not opened—natural size.

The large fig. is the human egg about the 21st day, natural size, opened, showing embryo with its yelk sac within. It is already attached to the inside coat of the egg by a short navel cord, and some of the gill arches, the rudiments of the fore limbs, and of the ear, eye, and heart, are begun. (*Allen Thompson.*)

CHAPTER IV.

COMPARATIVE DEVELOPMENT.

At the end of four weeks, of human embryonic age, the development has passed through some of the most important stages. Thus the heart has reached its four chambered stage, the lungs are commenced, the primitive kidneys in full operation, the liver begun, the intestinal cavity open from mouth to anus, both of which openings are already formed, the short, paddle-like limbs are started, the tail is quite prominent, and the jaw processes and the eye and ear indentations are commenced.

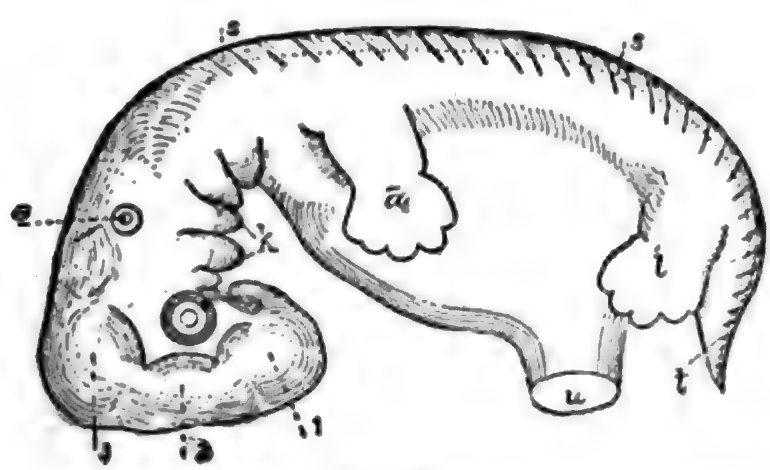
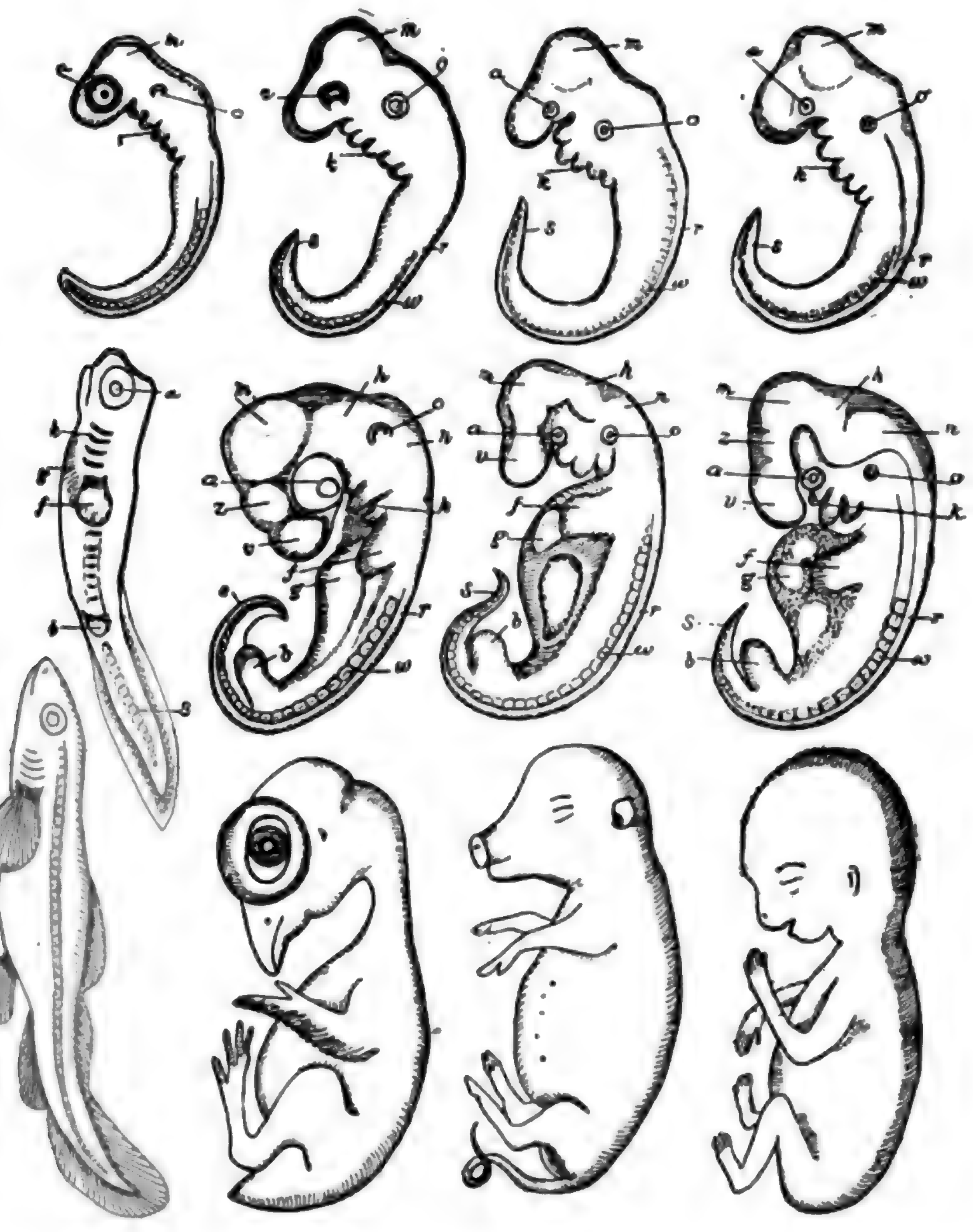


FIG. 32.

FIG. 32.—Human embryo—7 weeks. (Magnified about 7 diameters)—after Quain. *ss.*—Indications of vertebræ. 1, 2, 3.—Brain bladders. *k.*—Gill arches for a younger embryo. *e.*—Ear. *a, l.*—Arm and leg. *t.*—Tail. *u.*—Umbilical opening.

At this stage of human development the embryo is in all essential particulars the counterpart of the embryos of all the higher mammals. Some of the parts may differ in relative size, but the corresponding essential parts are present in all, and it would require an expert to tell the difference between the human embryo of four weeks and that of a horse, ox, dog or rabbit at its corresponding stage of development. If



FIGS. 33, 34, 35, 36, top row, represent the embryos of fish, chick, hog, and man, at an early age.

FIGS. 37, 38, 39, 40.—Same at a more advanced period, after formation of limbs and brain bladders, &c., has begun.

FIGS. 41, 42, 43, 44.—A still more advanced age, in which gill openings are lost (except in the fish) and the limbs more developed. The figures are magnified, the top ones the most. The allantois, yelk sac and amnion are left off. Letters the same in all.

v.—Fore-brain.	*r.*—Spinal marrow.	*f.*—Fore limbs.
z.—Twixt "	*w.*—Vertebral column.	*b.*—Hind "
m.—Mid "	*a.*—Eye.	*s.*—Tail.
h.—Hind "	*o.*—Ear.	*k.*—Gill arches.
n.—After "	*g.*—Heart.	(*After Hæckel.*)

the human embryo, under the age of four weeks, be compared with the embryos of other animals, the resemblances obtain, not merely with reference to the higher mammals, but with reference to all vertebrates. And in its very earliest stages it cannot be distinguished even from certain of the invertebrate animals. On the other hand, its development after the age of four weeks gradually separates it from that of all inferior animals. Its resemblance to that of the higher ape tribes, however, continues almost up to the date of birth. It is this remarkable unity of early embryonic life amongst the various members of the animal kingdom that proves the common origin and blood relationship of all.

But there must be degrees of consanguinity between the different animal tribes, and man cannot be related to all alike.

Assuming provisionally the correctness of the genealogical table constructed by Hæckel, we will compare the different members of the genealogical tree with each other, and note those points of resemblance between them in form and development, which are relied upon to prove their common ancestry. (See table, chapter 6.)

As previously mentioned, there are four various modes by which, amongst different classes of animals, the formation of the embryo from the single celled egg proceeds. The distinction between the four processes relates to the manner of splitting up the cells, called segmentation, and to the manner of forming the cells into the plates or layers, which is called gastrulation.

There are two main divisions of eggs. In one division, called the "holoblastic," the egg is all used up in the process of segmentation or cell cleavage, it being all *vitalized* or fertilized protoplasm. After its gastrulation is completed, the further growth and development of the germ plates depend upon the supply of nourishment from sources outside of the egg.

In the other main division, the egg is called "meroblastic." In this the egg is composed of two parts, the vitalized part, which is subject to cleavage growth and repeated segmentation, and a yelk or deposit of nutritive matter which never undergoes cleavage, but is gradually consumed as food or nourishment by the vitalized part.

Each of these main divisions is subdivided into two. In the first subdivision of the holoblastic type the segmentation of the original egg cell proceeds until the embryonic mass is reduced to a ball composed of cells packed together like the fruity globules of the blackberry or mulberry, and at this stage it is called the mulberry germ or "morula." In the further growth and expansion of the ball, the cells form a spherical sheath or cover, and the center becomes a hollow filled with protoplasmic fluid. In this stage the embryo is called a blastula. One half of the cells are dark and the other half bright.

This ball next undergoes an inverting process called "invagination," in which the dark side of the ball is in appearance gradually pushed into the interior hollow so as to form a lining for the bright side. The two layers thus form in succession a cup and a bell. Subsequently the more rapid growing of the bright or outer layer of cells turns the bell almost into a globe, having the bright cells for its outside and the dark ones for its inner wall. From these two layers the body of the future animal is developed, the outer layer forming the skin and hard parts of the body, and the inner one, the stomach and internal organs. This gastrula is called the "bell gastrula" or (Hellenized) "archigastrula."

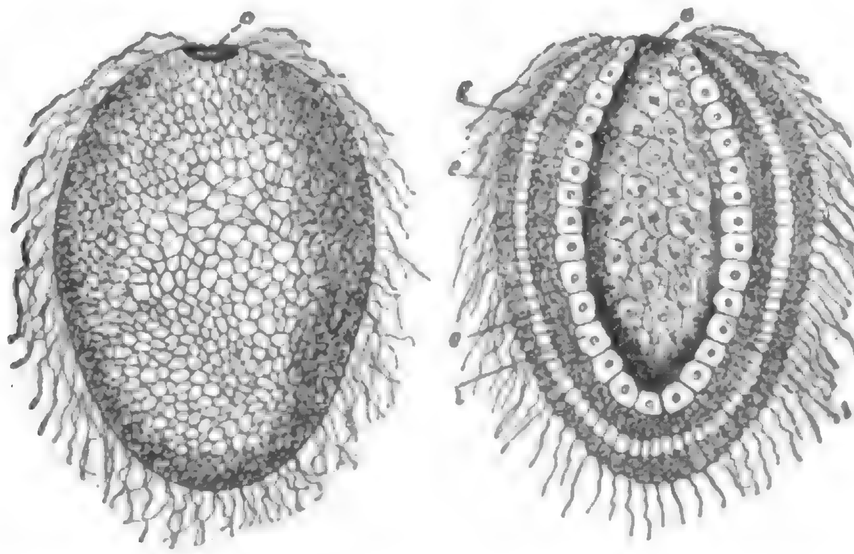


FIG. 45. FIG. 46.

FIG. 45.—The gastrula of a chalk sponge (Olynthus) covered with cilia. An external view.
FIG. 46.—A vertical section of same. *o.*—Mouth—(and anus). *g.*—Primitive intestinal cavity. *e.*—Exoderm or skin layer. *i.*—Entoderm or intestinal layer.

In the second division of the holoblastic eggs, the gastrula is called the hood gastrula. It is the type from which all mammals, so far as known, are developed, and has been described already. In it the outer layer of bright cells grows around into a hollow sphere, and the inner or dark layer subsequently lines it by growth upon the inside.

In the third subdivision, the cleavage is said to be "discoidal," because when the parent egg undergoes segmentation it does not take the form of a sphere or ball, but that of a disc or plate, lying on top of the nutritive yelk, which is comparatively an enormous ball, often many thousand times greater than the vitalized cell—a hen's egg is an example. The continued segmentation of the cells of the first plate or disc results in the production of a second, a third, and finally a fourth plate or layer, and the various parts of the future animal are derived from these four plates.

The fourth type of egg cleavage is that called the superficial cleavage, forming the "bladder gastrula." In this the segmentation of the

parent or germinating cell proceeds in such a manner as to carry the layer of bright cells quite around the nutritive yelk enclosing it as in a bladder, from which it is called the "bladder gastrula" or (Hellenized) "perigastrula." The formation of the dark layer is effected later, and inside of the bladder, beginning at one side where the bright membrane suffers an indentation from which the dark cells spread themselves so as to line the sphere, gradually consuming part of the yelk in the process.

All the animals in the world that grow from an impregnated egg, pass through one or another of these four forms of gastrulation. Some of the protozoa, including the gregarinæ and the monera amœba, and other rhizopods, do not pass through any type of gastrula, for the reason that they do not spring from an egg at all. Many of them consist of only a single cell, and when that cell is grown to maturity by the absorption of nourishment, it undergoes one single cleavage, and no more, each half becoming a complete animal with all the powers of the first cell.

There are other animals of minute and simple organization, among the flagellata and other infusoria, that develop to the *form* of a bell gastrula, but still, according to Huxley, may consist of only a single cell. And they continue their species, as all single cell animals must, by the splitting of the cell into two. The bell animalcule is an example.

There are also other minute and simple animals that rise above the single cell and develop to some stage between the single cell and the gastrula or cup form. Some of these stop at a development equal in value to a morula or mulberry germ.

There are many rhizopods that are in reality associations of simple cells all alike, and each cell a separate organism, that is, the animal is an association of single cell animals, each of an equal and homogeneus nature, the whole mass forming an animal called compound, but whose functions and faculties are not superior to those of any cell composing it. This sort of an animal is of the structural and functional value of a germ morula. Hæckel names the "cystophrys," described by Archer, and the "microgromia socialis" and "labyrinthulæ, described by Richard Hertwig, as special examples in point (see Evolution of Man, 2—58), still other mature and complete animals have substantially the form and value of the blastula germ, a remarkable example of which is the flimmer-ball or "magosphaera planula," as named by Hæckel.

The gastrula stage of animal development, at the present day, is a correct representation of a mature animal, which Hæckel names the gastræa, which in very ancient times developed from protozoan or amœboid forms.

When we rise into the animal subkingdom *cœlenterata*, we find numerous varieties whose mature development is only equal to a bell gas

trula. The animal consists of a double skin in the shape of a bag or sac. The outside skin is the ectoderm and the inside or lining is called the entoderm. It propagates by means of ova or female cells impregnated by male or sperm cells.

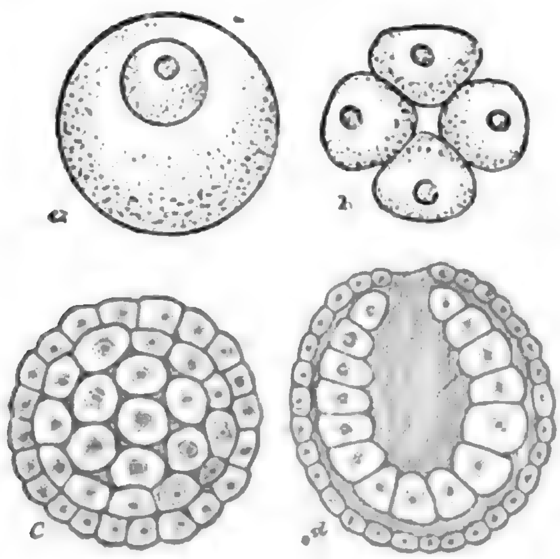


FIG. 47.

FIG. 47.—Egg cleavage and gastrulation of the ascidian (sea squirt). *a.*—Parent egg (cytula). The natural size is from 1-10 to 1-5 of a millimetre in diameter. In the interior is the nucleus 1-50 of a mm. in diameter enclosing the nucleolus. *b.*—Cleavage into 4 cells. *c.*—Germ vesicle or bladder formed after repeated cleavage—now called blastula. *d.*—The gastrula (*bell* gastrula), formed from the blastula by invagination. Hæckel.

In some cases both kinds of sexual cells are developed from the ectoderm cells. In other cases the sperm cell is an ectoderm cell and the ovum is from the entoderm. Many of these gastread animals have some adventitious or incidental appendage of more or less advantage to them, as cilia or hairs and stems or stalks, by which they are fastened to some object. But the vital and essential part of the animal when mature is nothing more nor less than a gastrula of the bell type. The embryos of the following animal varieties, as given by Hæckel, pass through this form of the bell gastrula, viz: (*a*) most of the plant animals, as low sponges, medusæ, and corals, hydrapolypes; (*b*) many low worms (sagitta) phoronis, ascidia, many nematodes; (*c*) a few mollusca terebratula, argiope, pisidium; (*d*) most star animals (echinoderma); (*e*) a few low articulates (some branchiopods, copepods, tardigrades); (*f*) skulless vertebrates (amphioxus).

The above list contains no animals of a high order. There is in it only one vertebrate and that the lowest of all, the amphioxus. Since they are not viviparous it is clear that they could scarcely survive through a gastrula form, which depends upon nourishment from without, unless they lived in a fluid element. Therefore, they are all inhabitants of water or other fluid, or are parasites in moist parts of other

FIG. 48.—Development of the gastrula of an amphioxus (lancelet). First fig., parent cell. Third fig., mulberry germ. Fourth fig., mulberry germ in section. Fifth fig., invagination begun. Sixth fig., bell gastrula.

animals. It would seem that for animals to live upon land, a modification of the gastrula would be necessary, or else the parent animal would have to nurse the eggs till the young animal could be hatched, that is, the parent would have to be viviparous. And such is the fact. All the land animals that develop through a gastrula without nutritive yelk, are viviparous, while all that develop through such a gastrula that are not viviparous are aquatic. The hood gastrula is certainly a more complex organism than the bell gastrula, and it includes the highest grades of animals in its type. But it also includes some very low forms, a fact significant of the genetic relationship connecting the highest with the lowest animals. The following are most important divisions of animals passing through the hood gastrula stage:

(*a*) Numerous plant animals (many sponges, medusæ, corals, siphonophores, ctenophoræ).

(*b*) Most worms.

(*c*) Most mollusca.

(*d*) Individual star animals, (viviparous species, and a few others).

(*e*) A few articulates (arthropoda) both crustaceans and tracheates.

(*f*) Cyclostoma, ganoids, amphibia, mammals.

To the disc gastrula type belong the following:

(*c*) Cuttle fish or cephalopods.

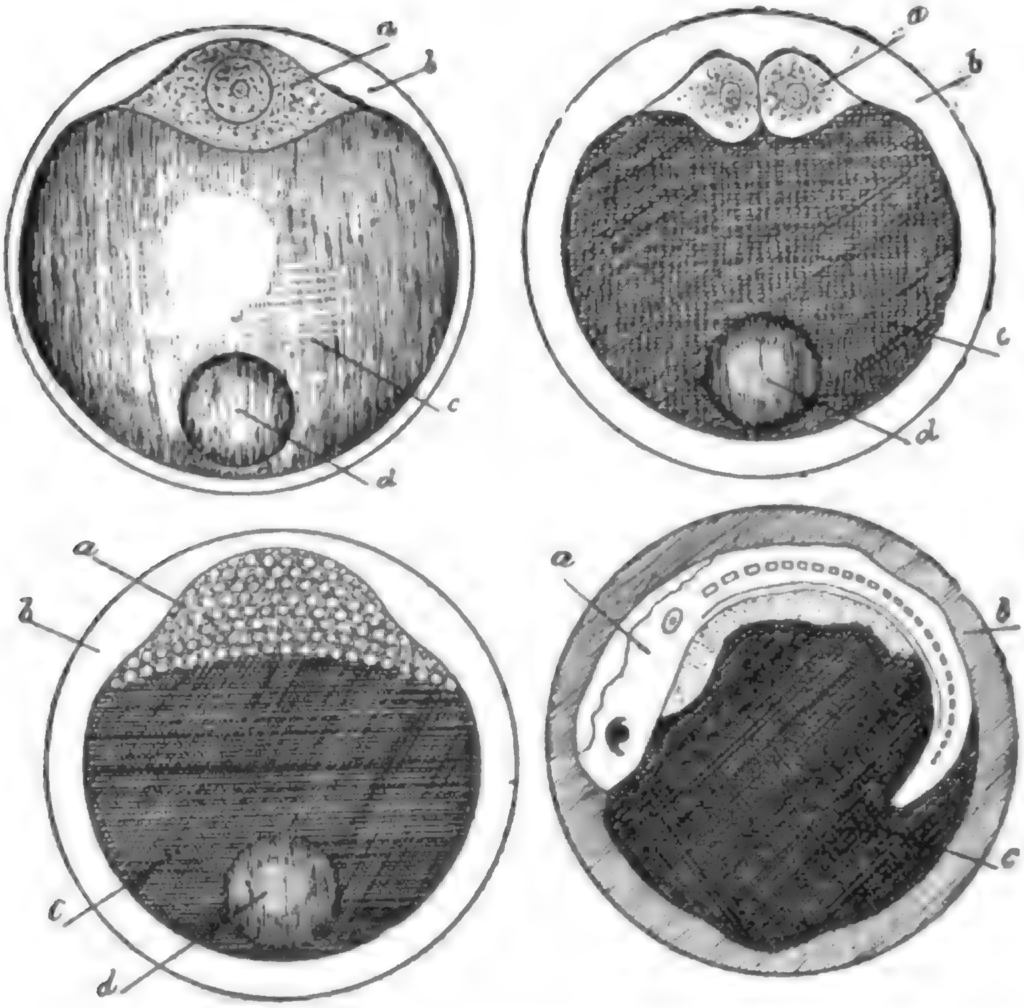
(*e*) Some articulates, as millipedes, scorpions and others.

(*f*) Primitive fishes (selachii), osseous fishes, reptiles, birds, (and monotremes.)

To the last, or bladder gastrula type, belong the great body of the articulates—(arthropoda) crustaceans, myriapods, spiders and insects, and probably a few sponges and worms.

Of the four gastrula forms, the bell is certainly the simplest and the first in point of time. The subsequent modifications from it, though apparently small, involve at last important results, as will be seen further on.

The science of embryology has proved that every organized individual on earth, begins life as a single celled animal. All organized individuals of the higher and more complicated forms, pass from their sim-



FIGS. 49, 50, 51, 52.

FIG. 49.—Egg of cod. *a.*—Germ with nucleus. *b.*—Egg membrane. *c.*—Ball of nutritive yelk. *d.*—Globule of fatty matter.
FIG. 50.—Beginning of segmentation of germ disc—(2 cells). Letters same.
FIG. 51.—Mulberry germ of disc gastrula. Letters same.
FIG. 52.—Little fish formed from the disc within the shell.

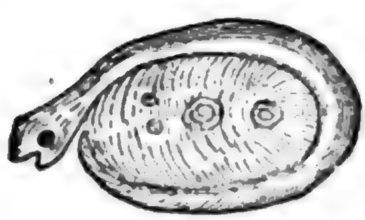


FIG. 53.

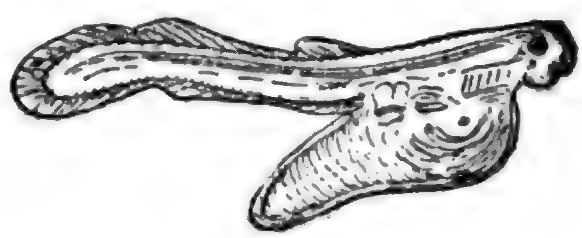


FIG. 54.

FIG. 53.—Young salmon just out of the egg, surrounding its yelk sac.
FIG. 54.—Young salmon three or four days out of the egg—swimming with yelk sac attached.

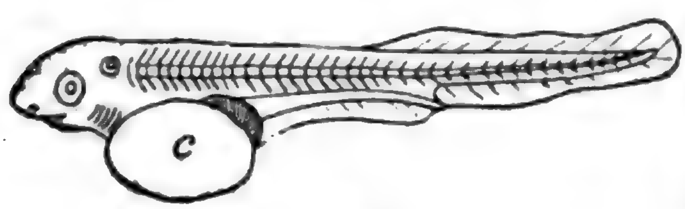


FIG. 55.

FIG. 55.—Little white fish escaped from the egg and swimming about with the nearly exhausted yelk sac c still attached to him. This he does about 60 days after the egg is laid, but his development is still very incomplete—mouth is underneath, teeth not formed, fins have no rays, and the gill covers not yet formed. Yelk sac diminishes daily and soon disappears.

ple existence as a cell by metamorphosis and modification of the cell into other forms, and their continued growth to maturity consists simply of a series of continued metamorphoses and modifications, each one of which depends upon and is based upon the one that preceded it in time. Each stage of growth is therefore the stage that preceded it—

plus the modification. This *plus* is to be taken in the algebraic sense, since every modification may not involve an increase in the complexity of the organism or its functions, and the addition of a subtractive modification will produce retrogression, of which instances often occur.

Embryology shows further that although there are animals of every grade of organic and functional development, every one of them passes through substantially the same modifications, as far as it goes, as the rest do. This is the point already shown in the comparison of the embryo germ forms with the mature animals of the protozoan and infusorial types. Every mammal, including man, therefore, while passing through the germ form morula, is in structure equivalent to a minute amœboid or rhizopod animal composed of homogeneous cells, of which multitudes inhabit all waters. Next, man is a blastula germ, structurally equal to the mature Norwegian flimmer-ball, and substantially equal also to the blastula germs of many other animals belonging to different sub-kingdoms, classes and orders, from animals as simple as sponges and worms, to the more complicated amphibians and mammals. Amongst some of the simpler animals, as corals, sponges, &c., the embryo, while it is a blastula germ, is of the nature of an independent animal, and is locomotive and self supporting in this as well as in the further stages of its development.

When the human germ reaches the disc form, in which it consists chiefly of the two primary germ layers, its structural value is that of a large class of simple animals, the zoophyta or plant animals, hydrozoa, corals, seafirs, jelly fish or medusæ, &c. These are, at maturity, composed of only the two skins, the entoderm and exoderm. In these animals the two skins are differentiated very slightly from each other, the entoderm acting as the stomach and superintending the personal economy of the animal, its digestion, nourishment, &c., and the ectoderm, being on the outside, receives the impressions from the environment and sustains the relations of the animal to the outside world. The differentiation in many cases, is so slight, however, that the animal may be turned inside out, and the two skins will readily exchange offices. From this stage in the human being, the differentiation becomes pronounced, the principle throughout the development of the embryo being that indicated in the two skinned hydra, the outside skin developing all the organs that relate to the environment and maintain communication with it, as, the outside skin, the organs of locomotion, including the bones and muscles which are necessary to it, the nervous system, brain, and all the organs of sensation—touch, taste, smell, sight and hearing: while the inside skin maintains the internal economy of the organism in the development from it of the machinery of digestion and assimilation—the stomach, liver, heart and other blood vessels.

It is on account of the striking divergence of the functions and outgrowths of these two germ layers that caused Baer to give them the very appropriate titles of animal layer and vegetative layer, terms indicative of their relationship to each other throughout the animal kingdom; a relationship founded upon the necessity of every organized being, of having domestic relations and foreign relations.

In the four layer stage of the human embryo its value is equal to that of a simple worm. A worm is, it is true, a finished animal, inasmuch as the plates are closed around making a series of four tubes, one within another, while the closing of the tubes in the human embryo is deferred while additional developments and alterations are being made in them.

By the time the closing of the four human embryonic layers is accomplished, the embryo has passed through several worm stages, including the simple one of the four plain and scarcely differentiated germ layers which have their equivalents in the embryos not only of worms but of all the vertebrates; the slightly differentiated forms of the bloodless worms, acœlomi, and the more complex organisms of the blood-bearing worms or cœlomi. The distinction between the acœlomi and the cœlomi is, that the former have not, and the latter have, a cœlom or body cavity. This body cavity is formed, as already described, by the separation of the outside skin (exoderm) from the inside (entoderm). When the two are formed into tubes, while the inside tube or sac fits neatly and closely into the outside one, there is no room for stowing away the system of blood vessels and other machinery for the elaboration and purifying of the nourishment required for the higher grades of animals. But in the advance of organic structure, as organs become necessary to assist the primitive intestine in elaborating the food, they make room for themselves by separating the ectoderm from the intestine, and into this space they are crowded. All animals without this body cavity are bloodless, that is, have no circulation of the blood.

By the formation of the body cavity and the differentiation of the gill arches from the front end of the intestine, and by the introduction into it first of the rudimentary kidney ducts for the excretion of the waste matters, and the development of the two blood tubes above and below the intestinal tube, together with the rudimentary system of nerves, the human embryo attains to the organic value of a higher grade worm, such, for instance, as the acorn worm, Balanoglossus.

In the acorn worm, and in all other animals with gills, the gills are at first slits in the front end of the intestine, and also, later, in the outside skin or exoderm. The part of the intestine thus set off to the use of gills, is called the gill body, and between it and the hind end of the intestine a constriction is developed, which becomes the œsophagus.

When the human embryo develops the notochord, the forerunner of the backbone, it imitates the appendicularia, and the *embryo* or *larval* form of the seasquirt—ascidian, which are the lowest animals pos-

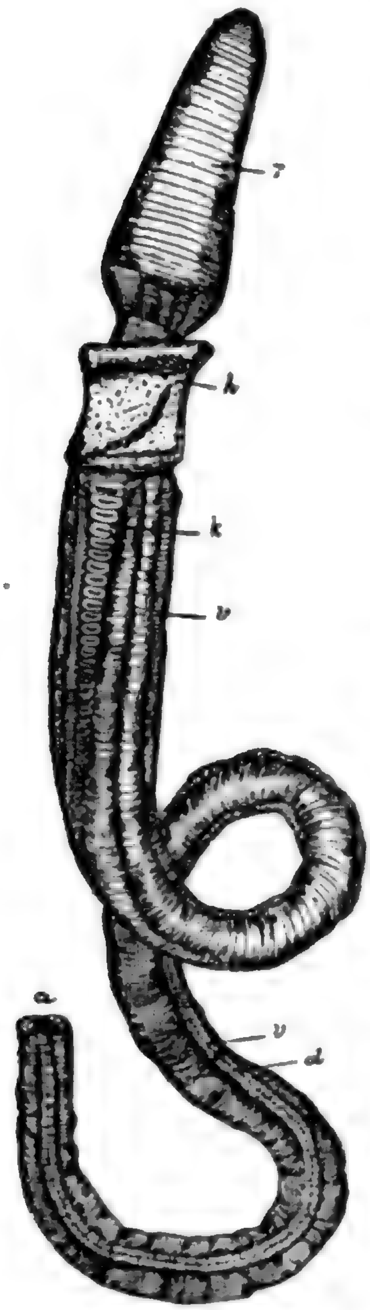


FIG. 56.—Balanoglossus, a young acorn worm. (Alex. Agassiz.) 7.—Proboscis. *h.*—Collar. *k.*—Gill arches and gill openings of anterior intestine, a long row on each side. *d.*—Digestive posterior intestine filling the greater part of the body cavity. *v.*—Intestinal vessel lying between two parallel folds of the skin. *a.*—Anus.

sessing the notochord, although the amphioxus is reckoned the lowest vertebrate now in existence. The supposition is that some worm-like animal, unlike any of these three, and now extinct, was the original possessor of the notochord, transmitting it to a posterity from which diverging forms have arisen.

The essential parts of the appendicularia are the mouth, the gill intestine, the œsophagus, the stomach and the anus, altogether forming the opening through the body; a simple tube shaped heart, some simple knots of nerve ganglia, a simple ear vesicle, long tail with notochord or rudimentary backbone, and testes and ovary (hermaphrodite). The ascidian, another tunicate animal, has a development similar to that of the appendicularia. In the larval state the ascidian is a freely swimming animal, with a tail containing a notochord like the appendicularia, and a rudimentary medullary tube, but when it reaches maturity it loses its tail and notochord, the medullary tube shrivels up forward into a permanent bunch of nerves called the throat ganglion, and the animal becomes fixed to a rock, or other stationary object, by its tunic. This is a wood-like, cellulose case of leathery consistence, which grows around the animal. In this case the soft animal, instead of lying or standing at full length, is doubled upon itself so that the end of the intestine with its anal opening, points upward. Its discharge is into the cavity of the tunic, and the outlet from the tunic is at its top, near the animal's mouth. So it stands, as it were, upon the middle of its intestine. Near this middle is the heart, which is an organ with a single cavity. From the heart a single blood vessel extends forward or upward to the gill sac, and another, from the other end, extends upward in the direction of the intestine, which is the same as backward. The heart has a slow pulsation, contracting first at one end and then the other, by which movement the colorless blood is

driven forward toward the gill sac, then backward toward the hind end of the intestine, so that each blood vessel becomes alternately an artery and a vein.

There is therefore no circular movement of the blood as in the vertebrates. Nor is it like the circulation of the worms and insects. For in

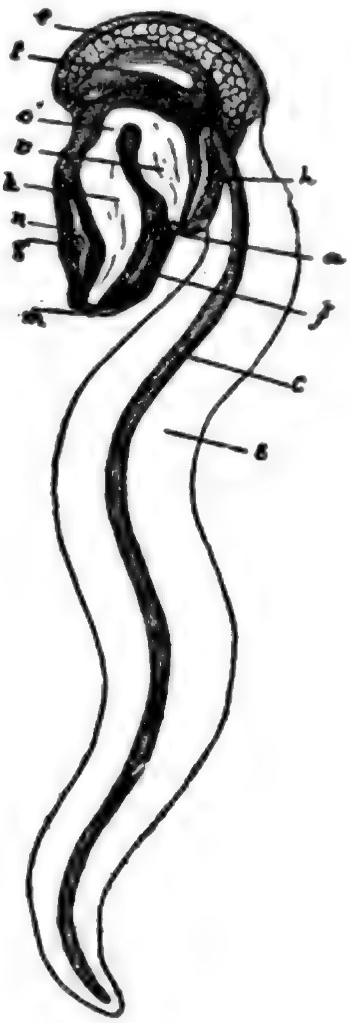


FIG. 57.

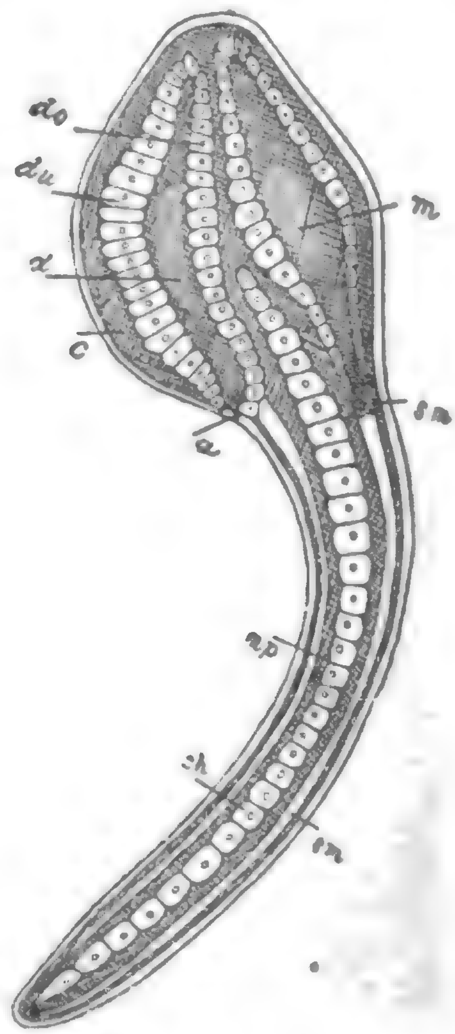


FIG. 58.

FIG. 57.—Appendicularia. *m.*—Mouth. *k.*—Gill intestine. *o.*—Esophagus. *v.*—Stomach. *a.*—Anus. *n.*—Nerve ganglia—(upper throat knots). *g.*—Ear vesicle. *f.*—Ciliated groove under the gill. *h.*—Heart. *t.*—Testes. *e.*—Ovary. *c.*—Notochord. *s.*—Tail. (Hæckel.)

FIG. 58.—Diagram of ascidian—larva freely swimming. The notochord—*ch*—is inserted between the medullary tube—*m*—and the intestinal tube—*d*—and passes through the long rudder-like ta l to its extremity. This tail and notochord are lost when the animal reaches maturity and settles down on a rock or something and becomes stationary for life. *m.*—Medullary tube. *sm.*—Spinal marrow. *ch.*—Notochord. *mp.*—Muscle plate. *a.*—Anus. *do.*—Dorsal wall of intestine. *du.*—Ventral wall of intestine. *c.*—Gill cavity. (Hæckel.)

these the blood moves forward in the dorsal vein to the head, and back through the body or the ventral vein, if there be one. In the fishes and other vertebrates, the blood passes backward along the dorsal vessel. So this ascidian circulation is a transitional stage between that of the worm and the vertebrate, as the ascidian himself is a connecting link between the worm and the vertebrate.

The heart of the human embryo is at first just such a one as the ascidian heart, but it remains a single heart a very short time, and its single cavity is soon divided into two by a partition or septum.

In this double cavity form the human embryonic heart is the same as that of a fish. And the circulation through it is also essentially fishy.

The blood passes into the rear or lower cavity of the heart by two principal veins leading from the yelk sac, and passes out from the front cavity by two aortæ that subdivide into five gill blood vessels, which, passing up by way of the gill arches, unite above and pass backward above the intestine. In the fishes this arrangement is permanent and is

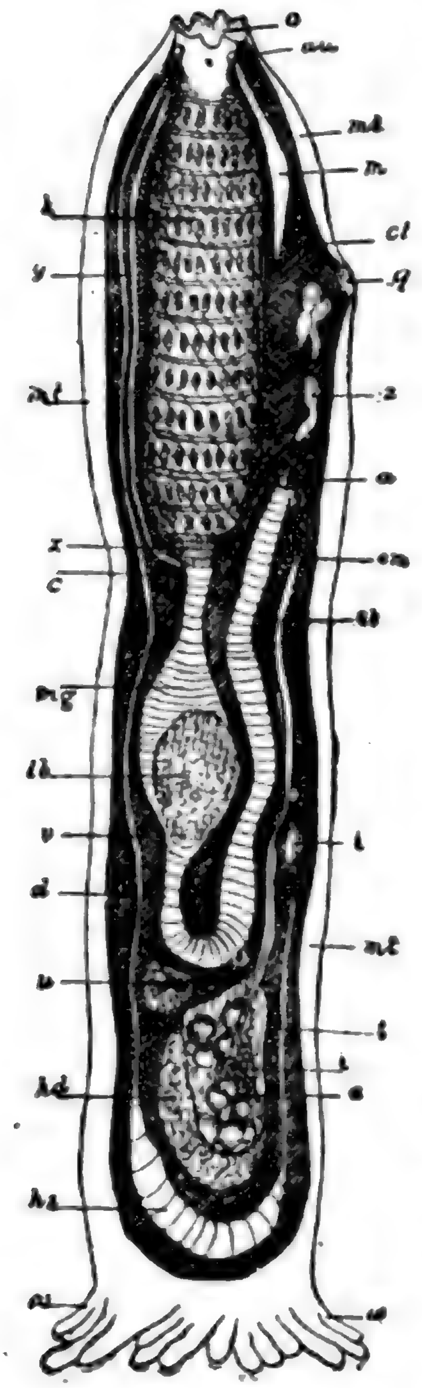


FIG. 59.—Adult ascidian. *a.*—Anus. *au.*—Eye. *c.*—Gill cavity. *cl.*—Cloacal cavity. *d.*—Intestinal tube. *e.*—Ovary. *hd.*—Testes. *hz.*—Heart. *i.*—Eggs. *k.*—Gills. *lb.*—Liver. *m.*—Medullary tube. *mg.*—Stomach. *mt.*—Mantle. *o.*—Mouth. *q.*—Cloacal opening. *sl.*—Seed duct. *sm.*—Opening of seed duct. *t.*—Aorta—(dorsal blood vessel). *u.*—Side canals. *v.*—Intestinal vein (ventral blood vessel). *w.*—Root-like attachments of the mantle. *x.*—Boundary between gill intestine and stomach intestine. *y.*—Hypo branchial groove. *z.*—Embryos of the ascidian.

necessary to convey the blood to the gills, to be oxydized by contact with the water. But as it has no such use to the human being, or other mammals, nor to birds, nor to reptiles, except some amphibians, and reptile larvæ, such as tadpoles; a part of these gill blood vessels and the gill arches themselves, are entirely suppressed or else turned to other use. A part of the vessels persist and are found in all vertebrates, including man—see figs. 26, 27, 28, 29. The gill *leaves* are not developed in the embryo of any *amnion* animal.

In connection with this modification of the fish breathing apparatus in the human embryo is the development of the lungs. These occupy the same place and are formed in the same way as the swim bladder of fishes, from the ventral side of the forward end of the intestine just back of the gills. At first a single vesicle, it soon divides into two, one left and one right. All vertebrates have this vesicle except the amphioxus and the cyclostomi, the lowest two orders.

In the adult fishes this vesicle remains permanently filled with air, the amount of which may be increased or diminished by the action of the animal. In many fishes the bladder is double. In the mud-fishes, dipneusta, this swimming bladder first becomes true lungs. In the ceratodus, the Australian mud-fish, a low form (but large, being six feet long), the lung is single. But in the African mud-fish, protopterus, and the American mud-fish, lepidosiren, the lungs are double, and so they are in all the higher vertebrates, including man.

The heart of the human embryo, after passing through the fish stage,

develops a septum or partition in the single auricle, which, while it is unfinished and imperfect, makes it the heart of a lepidosiren, and when this partition is complete the heart, with its three full cavities—two auricles and one ventricle—is the heart of an amphibian. When finally

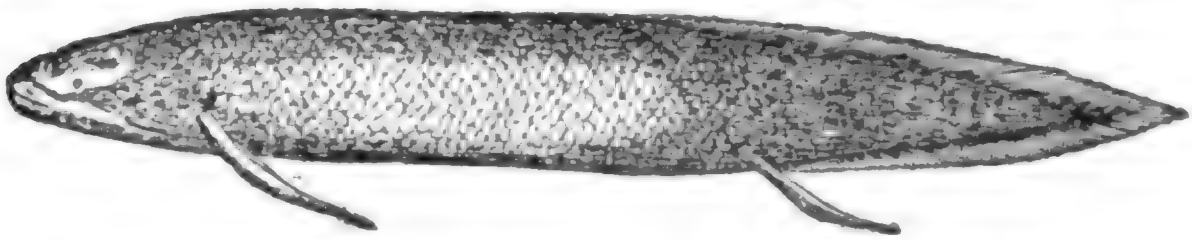


FIG. 60.—Lepidosiren—or mud-fish, protopterus, Brazil and Africa, 18 to 20 inches long.

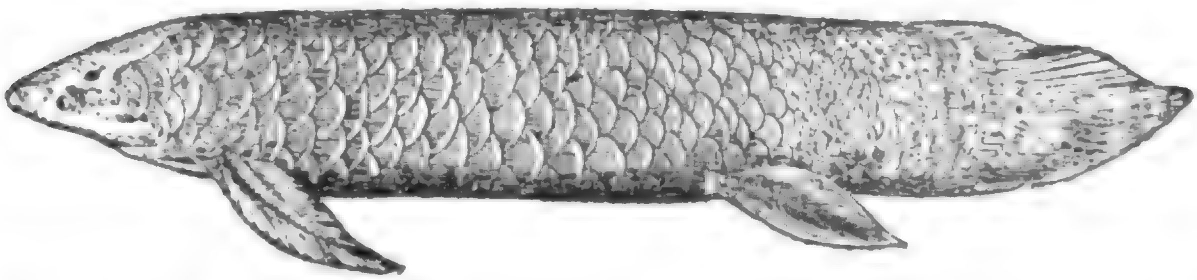


FIG. 61.—Ceratodus or barramunda. 3 to 6 feet long, of Queensland, Australia. These two fishes belong to the order dipnoi or double breathers—having both lungs and gills. They have a persistent notochord and scales, and are a cross between fishes and amphibians.

the ventricle is divided and the heart consists of four cavities, it is the heart of a monotreme (platypus). Still later, when the valves are perfected so as to secure the most economical mechanical action, it is like the heart of a marsupial or pouched animal. Lastly, it assumes the oblique position, common to the anthropoid apes and also permanent in the adult man.

So also in the development of the urinary and sexual systems in the human embryo the different stages are successively equivalent to the permanent arrangements of those parts in the lampreys, the primitive fishes, the dipneusta or dipnoi, the amphibia, the monotremes, the marsupials, and the edentates, and at last they become permanent in the human being in the same form as in the higher apes.

Other parts of the vascular system successively reach the permanent stages, as the same are fixed in the dipneusta, then the amphibia, then the monotremes, &c. The gill arches are one after another suppressed or changed to other use. While the last three of these arches are forming in the embryo, the first two disappear. The last three are modified into the permanent aorta and its branches, except a part that is suppressed, and another piece of the fifth arch that becomes closed and remains as a useless rudimentary organ called ductus venosus.

The blood itself is a progressively developed substance. The first form of blood is chyme. This, in the vertebrate animal, is simply the triturated and masticated food mixed with gastric juice. In the lowest animals there is probably little gastric juice in the mixture. Such as it

is, chyme is the only and permanent blood in the polyps, jelly-fishes, some mollusks and some worms. A second and improved modification of the blood is produced in the vertebrates by the mixture with it of the ferments called pancreatic juice, and bile. In this form in man it is called chyle. It is taken from the intestine by the lacteals, and carried by the thoracic duct and poured into the left subclavian vein, where it enters the general circulation and is changed to red blood in the passage through the lungs. The chyle or white blood is the permanent blood of insects, crabs and lobsters, most mollusks and some worms.

Lymph is a colorless fluid composed of nutritive matter of nearly the same composition as chyle, and in the higher vertebrates is gathered up by the absorption by the lymphatic vessels from all parts of the body, and through the skin (in some), and carried into the circulation by way of the thoracic duct and the right subclavian vein.

This lymph in the vertebrate body is made up largely from surplus

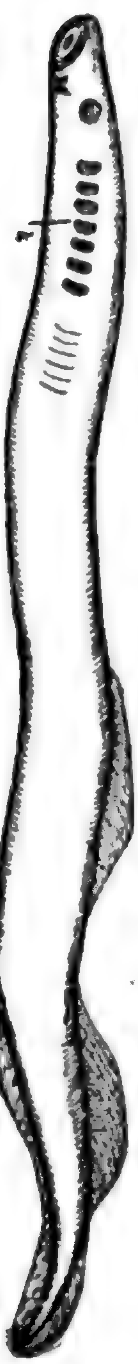


FIG. 62.—Lamprey, rock sucker.—(petromyzon marinus)—much reduced. Cyclostoma—round mouth—seven gill openings.

nourishment not needed by the tissues. In cases where some are better supplied than others with nourishment, or, as in starvation, the non-vital are required to yield their substance for the supply of the vital, the lymphatics do the work of absorbing and re-distributing the nourishment.

The first circulation of the mammal embryo is of colorless blood and is probably the equivalent of this absorbed lymph, and *is* absorbed—largely, at any rate—from the fluids of the mother.

The circulatory fluid of the lower vertebrates and higher invertebrates, is doubtless a mixture of chyle from the digested food and nutrient matter absorbed from without. The first true differentiated lymphatic vessels occur in the cyclostomi (lampreys, &c.). In frogs, and some other animals, large pulsating lymph organs are developed just under the skin. They are called lymph hearts, and they propel the lymph just as the heart does the blood.

In man, and other mammals, there are numerous glands attached to the lymphatic vessels. The lymph passes through these and is doubtless modified, and to a certain extent organized by them—although they do not pulsate as do the lymph hearts. The graded relationship existing between man and the other animals is well illustrated and indicated by these circulatory systems.

The brain and nervous system, too, pass through the same stages.

Beginning with a mere nervous filament in the lowest organisms, it appears in the star fishes with additional threads connected together so that sensation is conveyed from one part of the body to another.

In the mollusks are found knots of nervous cells by which the sensations are connected with each other. In the worms, a large knot or ganglion, placed above the throat and termed the throat ganglion, is the equivalent of a brain. In the amphioxus there is a spinal cord reaching from end to end.

FIG. 63.—Amphioxus lanceolatus. It has a pigment spot for an eye over the front end of spinal cord—also a small olfactory pit, no ear. C.—Cirri surrounding the mouth. KS.—Gills. Ov.—Ovary. L.—Liver. N.—Longitudinal folds supposed to act as kidneys. P.—Pore of the gill cavity. A.—Anus. Ch.—Notochord. RM.—Spinal cord.

In the cyclostomi (lamprey, &c.) there are five vesicles in a row, constituting a brain. In the development of vertebrates there are, at an early period, three brain vesicles, which, as mentioned above, soon form five.

From the three principal parts shown in figs. 64 and 65, all the rest are subsequently formed, the front forming the fore-brain and twixt-brain, which finally become the cerebrum and optic thalamus with their appendages; the hind part forming the hind-brain and after-brain, which, later, become the cerebellum and medulla oblongata, while the mid-brain bladder develops the corpora quadrigemina, the organs of sight. (See fig. 25.) Different parts of this complicated system of ganglions are developed in greatly different degrees in different races, according to their surroundings and habits of life.

The development of the brain in the human embryo, like the development of the other organs, passes successively through the various stages that are permanent in the various types of vertebrates below, and at last the brain is essentially that of the higher apes, possessing no organ or part not possessed by the apes. Not that there is no functional difference between the brains of men and those of apes, but it may be asserted that the difference is one of degree exclusively.

But there is not only a very close correspondence of organs and functions in the individuals of all the multifarious tribes of vertebrates, and a still closer one between those of the mammal tribes, but the same accessories of tools, instruments, appliances and temporary scaffolding, as it were, are used to build these organisms in all cases. It has been seen how all start from the impregnated egg, and increase their size by segmentation and the absorption of nourish

ment, and how all that pass a certain stage of development, continue their embryonic growth by feeding upon a bag of nutritive yelk. Astonishing as these correspondences are, the employment of the amnion and the placenta in the embryonic development of vast tribes of vertebrates, is yet more wonderful.

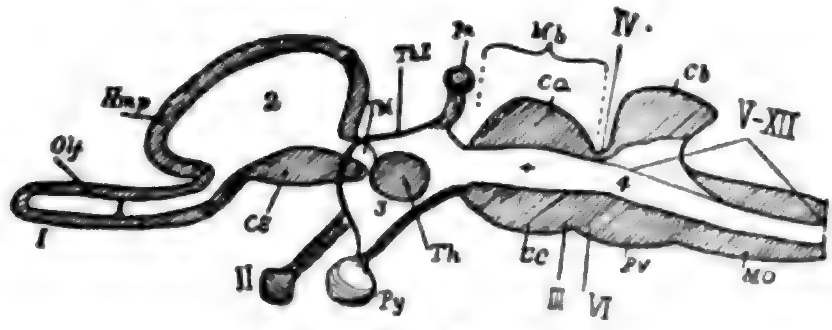


FIG. 64.

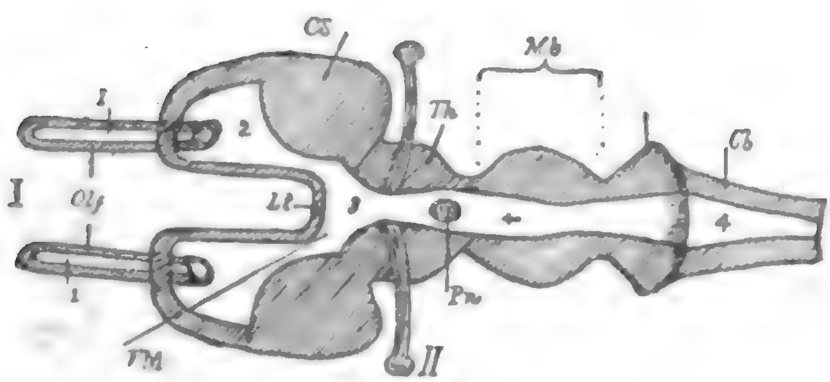


FIG. 65.

FIGS. 64, 65.—Diagrammatic, vertical and horizontal sections of vertebrate brain.
Mb.—Mid-brain—what lies in front of this is the *fore-brain*, that behind, *hind-brain*.
Lt.—Lamina terminalis. Olf.—Olfactory lobes. Hmp.—Hemispheres.
ThE.—Thalamencephalon. Pn.—The pineal gland. Py.—Pituitary body.
FM.—Foramen of Munro. CS.—Corpus striatum. Th.—Optic thalamus.
CQ.—Corpora quadrigemina. CC.—Crura cerebri. Cb.—Cerebellum.
Pv.—Pons varolii. MO.—Medulla oblongata. I.—Olfactorii. II.—Optici.
III.—Point of exit of the motores oculorum.
IV.— " " " pathetici.
VI.— " " " abducentes.
V-XII.—Origins of the other cerebral nerves.
1.—Olfactory ventricle. 2.—Lateral ventricle. 3.—3d ventricle. 4.—4th ventricle.
+.—Iter a tertio ad quartum ventriculum, or aqueduct of sylvius.
The heavy line in fig. 64, running from PN to Py, is lamina terminalis.
The space above the pituitary body or gland, and below fig. 3, is the infundibulum.
(*After Huxley.*)

The amnion and its manner of growth and use in inclosing and protecting the delicate embryo, has been described. The embryo of reptiles and birds, as well as of all mammals, are nursed in this amnion sac. It is impossible to overrate the importance of this astonishing fact in proving the blood relationship of birds, reptiles and mammals, and their descent from a common amnion bearing ancestor.

The formation of the placenta from the ancient and primitive urinary bladder, points out another but later family characteristic.

This primitive urinary sac is a blind sac growing from the front or belly side of the intestine near its hind end, and first appears as a permanent organ in the adult dipneusta (lepidosiren, &c.), and is an embryonic organ in the amphibia and all mammals, including man. In all the mammal embyros this urinary sac enlarges into the allantois or

"sausage-shaped" bladder. In all the higher mammal embryos—those above the marsupials—the allantois grows in length until it comes into contact with the walls of the uterus of the mother, with which it forms a partial union, and then it supersedes the yelk sac and becomes the vehicle of nourishment from the mother to the growing embryo. This process has been described. The attachment of the allantois to the uterus in man, is over a discoidal surface some 6 or 8 inches in diameter, and the membranes involved in the connection, some of which are furnished by the embryo and some by the mother, become the organ called the placenta.

While man is related to all the mammals above the marsupials, in the general fact that they all have a placenta, he is more nearly related to some than others, as shown by peculiarities regarding the placenta. Thus whales, sea cows, horses, cattle, &c., have what is called the indeciduate placenta. That is, only those membranes of the placenta which were contributed by growth from the embryo, are discharged from the uterus at the time of birth, while the mother retains the part of the placenta contributed by her. But the placenta of man, of the elephants, the beasts of prey, the rodents, the edentates, the bats and apes, is a *deciduate* placenta, so called because the mother gives up her own share in the placenta when it is delivered after the birth.

There is still another sub-classification in the *shape* of the placenta. In man, apes and rodents, the placenta is circular or cake-shaped, as stated heretofore, while in the elephants and in the carnivorous mammals of land and sea, the placenta is girdle-shaped, and is, in fact, a broad belt or ring of the chorion of the embryo, attached to the deciduate membrane of the uterus of the mother.

In the indeciduate placenta, the chorion tufts of the embryonic membranes, enter the soft vascular mass of the maternal uterus, sheaths of which form around the chorion tufts. When the birth takes place the tufts of the chorion pull out of their sheaths, carrying away none of the maternal uterus, as in the case of the deciduates.

In the case of the indeciduates, the attachments to the uterus are made upon all sides of the embryo, and the placenta is therefore in the shape of a hollow sphere. In the indeciduate girdle placenta, the attachment is over an equatorial belt of the spherical egg, the head and tail, or polar attachments of the sphere, being abolished.

In the discoidal form, the belt is reduced to a circular plate or disc. These progressive relationships between the different kinds of placenta, show the unity of the different animal races to which they belong, particularly, when it is considered that in the development of the chorion in all cases it is first covered with the tufts upon all sides—in man and apes as well as cattle and horses. But the man and the ape make no

use of a large part of these tufts and they are all subsequently suppressed, except those covered by the disc. Thus the chorion itself, which is only a temporary instrument, passes through an embryonic and rudimentary stage in all the deciduous mammals.

It is interesting to observe the gradual change which takes place in the period of egg-impregnation, as we ascend the scale of the vertebrate animals. In most fishes the unimpregnated eggs and spermatozoa are thrown into the water and allowed to find each other as it may happen. Millions of eggs are thus born, a vast number of which are never impregnated at all. In the amphibian also, the eggs are born unimpregnated, but the parents take care to bring the elements together so that impregnation is assured at the moment of the birth. In birds and reptiles the eggs are impregnated *before* their birth, but in birds, as all know, only a few hours before, and the entire development of the embryo takes place after its birth. In the marsupial the egg is not only impregnated but hatched before birth, but the embryo is hatched and born in a very unfinished condition. It is put into the mother's pouch and carried for a long time, before its development is completed. Amongst the higher mammals, the period from impregnation to birth, that is the period of gestation, increases as we go up the scale.

To the question, why does the vertebrate embryo show the gill slits and other marks of low stages of life, Wilson answers that it is because they represent those stages as the actual ancestral stages of the vertebrate possessing them ; they are legacies from the ancient state of the ancestral line. I would add, that in the building of any individual body, the parts can only be put together after the inherited pattern, and, therefore, in the inherited sequence. The body is like a Chinese puzzle, which goes together all right and easily, if the due sequence in putting the parts in one after another is observed; but if it is not, and any one is attempted to be placed out of its proper order, it will not fit nor allow any subsequent piece to fit. If your watch has been stopped an hour and you propose to set it, as you do so the hands will rapidly point, in succession, to each minute that they would have indicated in normal action.

When a man does a thing in a round-about way, just because his father did and because he *learned* to do so, we call him "old fogy." But nature does just so in development. She is used to making a man by making him first a fish, then amphibian, &c. &c, lastly, *altering* him into a monkey and a man. It looks like a mere matter of habit with nature, and so we shall see it is, when we properly understand what habit is—a question that is discussed further on.

CHAPTER V.

RUDIMENTS.

There is further and very striking evidence of the evolution of the higher forms of life from the lower, in the possession, in all of them, of rudimentary organs, so called. These are organs which to their possessors are useless, but which correspond to organs that in other animals are necessary and functional. They are usually more or less atrophied or reduced in size, and are totally without function, or become functionless during the life of their owner. The human ear-shell, for instance, with its muscles, is proved to be totally useless as to the function of hearing. It was developed in the early mammal races as an aid to hearing. It is still useful to the most of them, for they have the power to direct the shell in such a way as to catch a sound more perfectly. But the human race has, from long disuse of the ear muscles, almost entirely lost the power to contract them, and so the shell is reduced to a piece of immovable gristle of no use whatever. The ear muscles, whose use has thus been lost, are *attollens aurem* or *levator* for raising the ear, *attrahens* for drawing it forward, *retrahens* for drawing it backward, *helicis major* for pulling forward the front of the helix,

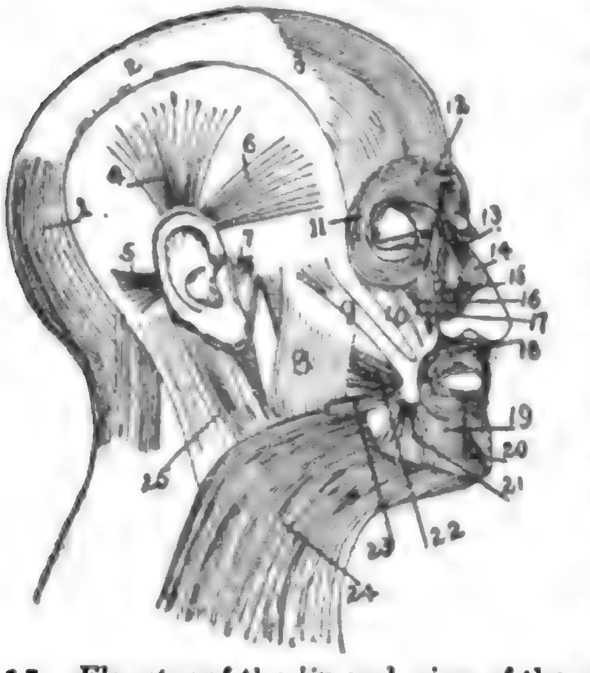


FIG. 66.—*Superficial muscles of head and face.*
1, 2, 3.—*Occipito frontalis*—when contracted it raises the eyebrows and wrinkles the forehead.
4.—*Attollens aurem*—raises the ear in lower animals.
5.—*Retrahens aurem*—draws it back.
6.—*Attrahens aurem*—draws it forward.
7.—*Tragicus*—draws forward the tragus or goat.
8.—Superficial part of the *masseter*—pulls up the jaw in chewing.
9.—*Zygomatic major* } pull up the upper lip
10.—*Zygomatic minor* } in laughing.
11.—*Orbicularis palpebarum*—a sphincter around the eye—closes the eye (cut off at the right to show No. 12).
12.—*Corrugator supercilii*—it lies under the *orbicularis* and *frontalis* (3); it draws the eye brows together and wrinkles the skin.
13.—*Pyramidalis nasi*—wrinkles the skin at the root of the nose, crosswise, and spreads the nostrils.
14.—*Compressor naris*—it either compresses or dilates the nostrils.
15.—*Elevator* of the *lip* and wing of the *nose*.
16.—Partly concealed—*elevator* of the corner of the mouth.
17.—*Elevator* of the upper lip—also pulls it slightly backward.
18.—*Orbicularis oris*—surrounds the mouth and closes it.
19.—*Depressor* of lower lip.
20.—*Elevator* of chin: and pushes up the lower lip.
21.—*Depresser* of corner of the mouth. 22.—*Buccinator*—Draws back the mouth.
23.—*Risorius* or laugher—it lengthens the mouth. It is a branch of the next.
24.—*Platysma myoides.*
25.—*Sterno—cleido—mastoid*—Connects sternum, clavicle and mastoid process.

helicis minor for contracting the fissure in the cartilage opposite the concha, *tragicus* for pulling down the tragus or "goat", and the *antitragicus*—belonging to the antitragus. This last muscle is entirely

wanting in some individuals. Fig. 66 shows the most important of the ear muscles. Occasionally we meet with a person who can work his ears. I know one who can throw off his plug hat I suppose with the *attrahens* alone; for it is said that while a few can use that muscle and the retrahens, no one can use any of the rest.

The lower apes as well as the other mammals generally, still use these muscles. The anthropoid apes, however, do not as a rule.

The anthropoid apes, as a rule, also share with man the round-edged folded ear shell with its flap. Darwin has shown that the *embryo* of some of the anthropoid apes has a long pointed ear, which is rounded off afterwards. In many cases the faint hint of this point can still be detected on the upper margin of the human ear. According to Darwin, the drooping of dog's ears is due to the atrophy of the muscles through disuse, since their domestication.

The remains of a *third eyelid* is found in the inside corners of the eyes of men and apes. It is simply in them a crescent-shaped fold of membrane, covering a very small part of the eye-ball. The fully developed membrane occurs in the primitive fishes, sharks, and some other animals. In them it is used to cover and protect the eyeball. The scrap of it left to man and ape is quite useless and immovable.

The *panniculus carnosus* consists of a thin muscular sheet immediately under the skin, which the quadrupeds use for shaking the skin to drive off flies. In man this muscle has largely disappeared, only three pieces of it being left, viz., the *occipito frontalis*, or muscle for moving the skin of the forehead, the *cremaster* muscle, and the *platysma myoides* or skin muscle, situated on the sides of the neck. We have no control of this last muscle, the office of which would be, if we could use it, to wrinkle the skin of the neck transversely. The *risorius*, however, which helps us to laugh, is reckoned to be an active part of the otherwise functionless platysma myoides. (See fig. 66—1, 3, 23, 24.)

The *thymus gland* is a body which is formed near the base of the heart. It is largely developed in the fœtus, and it continues to grow for two or three years after birth. After that time it remains without change for a period of from 7 to 12 years. Fatty degeneration then begins at the outer part of each lobule and proceeds inwards, and the organ loses its activity.

While the organ is functional it appears to be a lymph gland. In reptiles and amphibians, which do not possess other lymph glands, this seems to be sufficient in itself, and it remains active through their lives. It forms colorless corpuscles identical with the colorless corpuscles found in the blood. Useful in infancy, it is soon outgrown, and becomes a mere useless rudiment. It has become superseded by a more complete apparatus, and is in process of total abolition. It is an inherit-

ance persisting for a time **in each individual**, and then succumbing to adverse competition.

The *thyroid gland* is an organ, the use of which is a matter of conjecture, and in adult life it is commonly regarded as a rudiment. It lies in the front part of the throat, and is the part affected in the disease called goitre. It may be of some sort of use in embryo life, probably in influencing some of the secretions, but it is relatively smaller in the adult, and although found in the ascidian and among the vertebrates up to man, it is regarded by many as of no use, though perpetuated through habit. It is not a true gland since it has no excretory duct, but it has some sort of life since it has arteries and veins.

Perhaps it is a parasite, like a sort of hereditary tumor reduced to a definite habit of life and limit of growth. But is not every rudimentary organ a parasite?

The thyroid gland consists of numerous entirely closed sacs, 0.04 to 0.1 mm. in diameter, which are embedded in a connective tissue consisting of fibres and cells. The sacs contain a transparent, viscid, albuminous fluid, and sometimes also colored blood corpuscles. In the young animal the sacs are lined with a layer of cells. In the surrounding tissue there are numerous blood vessels and lymphatics. At an early period the sacs dilate their cellular lining and their contents undergo colloid degeneration.

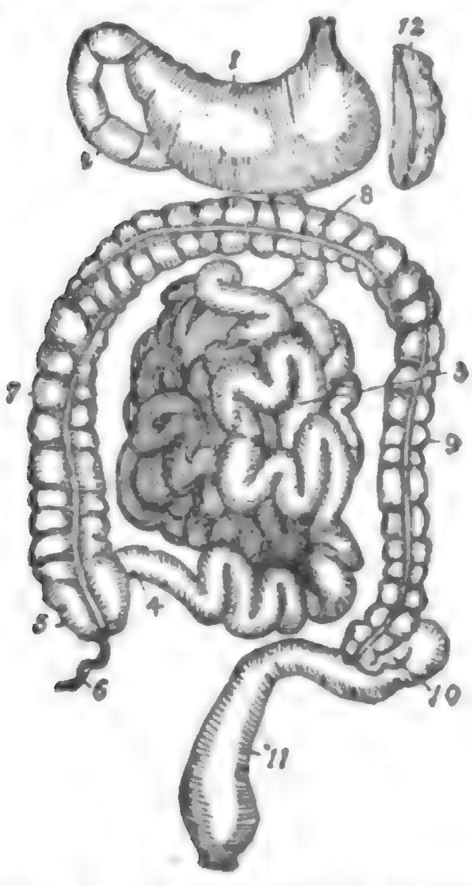


Fig. 67.—*Human stomach and intestines.*
1.—*Stomach.*
2.—*Duodenum.*
3.—*Jejunum.*
4.—*End of the ileum.*
5.—*Cœcum.*
6.—*Vermiform appendix.*
7.—*Ascending colon.*
8.—*Transverse* "
9.—*Descending* "
10.—*Sigmoid flexure* of the colon.
11.—*Rectum.*
12.—Position of *spleen.*
(Parts connecting spleen with duodenum, &c. are left off.)

The disease goitre consists of an extensive enlargement of the gland vesicles. This disease sometimes produces cretinism and so does the extirpation of the gland. This gland in the tunicates, is represented by a groove which secretes a digestive fluid. In vertebrates it is regarded by some as a blood corpuscle forming gland, and as a regulator of the formation of mucous in the body. Whatever its function in early life, it loses or totally changes it as age advances.

Another singular rudimentary organ in man and ape is the *appendix vermiformis* or worm-like appendage to the cæcum or blind intestine. It is the size of a goose quill and from three to six inches long. In some of the plant-eat-

ing animals the appendix is more or less a continuation of the cœcum, giving to that intestine needed additional size, but in man and the apes, whose food is more concentrated, the size is not required, so this section of intestine is atrophied. In the carniverous animals, it is also small or atrophied. The wombat, a marsupial, has the appendix, and it is found in the gibbon, orang, chimpanzee and gorilla. It is a source of some danger, as occasionally a grape seed, or some such object, gets into it, producing chronic inflammation with usually a fatal result.

The *intermaxillary bone* is another rudiment which the human family inherits from our relations below. It is a "bony portion wedged in between the two superior maxillary bones, which supports the upper incisors. This bone is found in the mammalia; and also in the human fœtus." * It is permanent in the adult ape, but is eliminated in human life and does not appear in the adult man.

Among the most remarkable rudiments in the human system, are those resulting from the ancient forms of the urinary and reproductive apparatus.

The *primitive kidneys*, or wolffian ducts, which are early developed in the mammal embryo, are equivalent to the corresponding organs as they exist permanently in the non-amnion craniota, cyclostomi (lampreys, &c.), fishes, dipneusta (mud fishes), and amphibia.

But to these primitive kidneys are soon added, in the mammal embryo, the permanent kidney and the müllerian duct, after which the primitive kidney duct is converted—in the male, into the testis and sperm duct, while the müllerian duct becomes the useless rudiment called the male uterus. (See fig. 30.)

In the female, on the other hand, the primitive kidney duct (or wolffian duct) is sunk into the useless remnant called the *parovarium* ("near the ovary"), while the müllerian duct becomes the fallopian tube and uterus. The significance of this remarkable development, cannot be mistaken. It shows that mammals have inherited, and all pass through the ancient invertebrate condition of hermaphroditism, in which both testis and ovary are formed in every individual. If all are blood relations and spring from a common hermaphrodite ancestry, this temporary possession of the rudiments of both kinds of sexual organs, is explained as hereditary. We have them because our ancestors had them, back through all the generations of mammal, lower vertebrate and invertebrate.

The forms of the organs have been infinitely varied and modified by the local and tribal necessities of the myriad races that have borne them, but the principle has been infinitely stolid and persistent.

The *male mammillary glands* are probably also an outgrowth of the

* Dunglison's Medical Dictionary.

ancient hermaphrodite nature of our prevertebrate ancestors—although, of course, not developed till long after their time. There are frequent examples, however, of the practical use of the male mammæ among some of the lower mammals and occasionally among men.

Practically, however, the male mammæ are rudimentary organs amongst all the higher mammals, including man.

Instances are given of cases of *reversion* in which more than one pair of mammæ have been developed. Darwin speaks of 5 cases of men who had 2 pair of the male rudimentary mammæ. Also women have been known with more than two pair. Two pairs of mammæ are normal with some of the Lemur families. (Descent of Man 37.)

The external organs of reproduction furthermore show in their development their sexual differentiation from the hermaphrodite original phallus or sexual protuberance of the embryo. Whether this phallus develops the male or female parts, the steps are similar and the parts are essentially the same in the two sexes, part for part. (See table XLIV in Hæckel's Evolution of Man.)

The *ductus venosus* or venous canal has been mentioned as a derivative or remnant of the fifth gill arch of the embryo. In the fishes this arch is permanent, and it is developed and temporarily used in the mammal fœtus, including man. "It extends from the bifurcation or forking of the umbilical vein to the vena cava inferior, into which it opens below the diaphragm. At times it ends in one of the infra-hepatic veins. It pours into the cava a part of the blood which passes from the placenta by the umbilical vein. After birth it becomes a fibro-cellular cord." (Medical Dictionary.)

On the human embryo, three or four months before birth, a delicate woolly covering called the *lanugo*, is developed. Shortly before birth, but in some cases just after birth, this wool disappears and true hair grows from the same roots as the wool; sometimes the hair differs in color from the wool. This wool covers all parts of the body except the palms and soles, as in apes and other mammals.

Human infants have the rudiments of *52 teeth*, while adults have permanently but 32. (Neil's Anatomy.)

The *tail* is another rudimentary organ. In the human embryo it is at first developed more rapidly than the limbs, and at one time is twice as long as the hind limbs. It is then furnished with muscles which are afterward re-absorbed. It does not after birth project beyond the skin in man or the higher apes, except in rare cases of reversion. As already noted, the number of vertebræ in the adult human tail is ordinarily four, in the gibbon (ape) three, in the chimpanzee, gorilla and orang, five, and from five to thirty-one in the tailed apes.

These tail bones, which, in the human infant, are separated from

each other as the rest of the vertebræ are, during youth grow together and become consolidated into one. This is a process of atrophy and a sort of acknowledgment on the part of nature that she has built a useless organ. In our remote mammalian ancestors, these bones remained separate during life, preserving the flexibility necessary to allow the tail to wag. But, although we have long since discontinued the use of a tail, nature continues patiently and aimlessly to build the stump as she used to do.

It is not likely that our posterity a million years hence, will be without this reminiscence, but the progressive process of atrophy will cause the consolidation of the bones to take place earlier in life, so that in time they will be solid at birth.

The tail is a venerable organ, dating back of the earliest vertebrates, and it has been of immense service to all the tribes, under its many modifications of form, as a rudder and propeller, as a fifth leg, as a switch-about, and as a prehensile organ, as in the case of many marsupials and monkeys.

Knox (Races of Men) observes that there are many people born into the world with some sort of deformity due to arrest of embryonic development. Some cannot extend their arms or legs to a proper degree; some have webbed fingers or toes; some have no arms but merely hands, like the whale; others, no legs but merely feet; some have hare lip. "On the best formed neck of man or woman, the finest openings may occasionally be seen—the remains of branchial arches or gills, which all animals, man not excepted, have in their fœtal state."

The *occipital condyles* in man, consist of two oval or oblong eminences on the bottom of the skull, one on each side of the great foramen or bottom opening of the skull. Their surfaces are smooth and convex, and articulate with two corresponding smooth surfaces on the top of the atlas—the first of the neck vertebræ. The skull, therefore, rests on these condyles. In the natural erect position of the backbone in man, these condyles are level or horizontal. In the lower animals they stand at an angle with the horizon. In the orang outang this angle is 37°; in the horse it is 90°.

"In the fœtal head the occiput consists of four pieces. The first piece, or basi-occipital bone of Owen, is separated from the two lateral portions by a fissure running through the condyles; this piece remains permanently separated in the cold blooded vertebrata, and in the African head also, the basi-occipital bone is frequently retained." The condyloid process is divided by a transverse ridge or groove into two distinct articular surfaces, which are often in different planes. This is the case in 30 out of 81 African skulls in Morton's collection, and in 4 out of 125 Caucasian skulls in the same collection. The condition of these con-

dyles and bones indicates the state of development of their owner.

It has been held that the valves in the portal veins which exist in certain animals, do not exist in man—but Dr. Bryant, of Worcester, Mass., has discovered that they do exist in the portal veins of infants a few weeks old, and disappear in the adult. (The portal veins convey the black blood from the intestines and the liver.)

Every other animal race as well as the human, has its rudimentary or atrophied organs. Those of the higher apes are mostly identical with ours. But in those branches of the animal kingdom that are not in our line or very nearly related to us, they are, of course, different. These atrophied organs are often useful in tracing the pedigree of the animal to which they belong. Thus the frog has on his hind limb, five digits. But on his fore limb he shows only four. He has, however, the other in suppressed form, concealed under the skin. The embryo of the whale has bony teeth, but when it grows up it has only the whalebone or baleen, the teeth being absorbed and never cutting the gums. The Deductor or Caing whale has from nine to thirteen teeth on each side, above and below, but loses them all with age. Some of the dolphin whales have teeth which they lose young, others have teeth which never cut the gum. The armadillo belongs to the edentates, or so called toothless tribes, which have, however, back teeth but no front ones. Its first teeth are covered with enamel like those of the higher mammals. These are lost, and behind them come up the permanent ones without enamel. Behind the primitive teeth are small sacs which correspond with the germs of the permanent teeth of the higher mammalia. (Baird's Annual 1874—289.) The above facts indicate that the whale has descended from a land mammal, and the armadillo from a diphyodont mammal stock, and the frog from a five-fingered, tailed amphibian.

The monotremes, ornithorhynchus and echidna are a sort of cross between birds and mammals. They have bodies like rats, and they suckle their young through pores in the skin leading into the milk glands, but they are destitute of nipples. Like birds they have no external organs of generation, and are furnished with a cloaca or common passage as exit for all excrementitious matters. (See fig. 30.) When young, the sexes are indistinguishable, both being alike even to the spurs which sprout on the hind leg of each. But in the course of growth, the spur on the female is suppressed while the male spur is fully developed like that of a rooster, and this constitutes the only sexual mark. They have a bill like that of a duck, and their feet are both clawed and webbed.

All the lower animals also pass, in their embryonic life, through stages of development corresponding to the permanent conditions of their predecessors. For example, the white fish when young bears a

close resemblance to a cartilaginous fish, such as the sturgeon (see fig. 55). Its mouth is on the underside of its head, its vertebræ are only cartilage instead of bone, and its tail is undivided. This is substantially the permanent condition of the sturgeon—except that the tail of the adult sturgeon is unequally divided—having a long prong above to the end of which the cartilaginous spine extends, and a short, fin-like branch underneath. When the white fish is grown, its mouth comes to the front end, its spinal column becomes ossified and the tail more equally divided, as in the osseous fishes. This proves the sturgeon type or cartilaginous type of fishes to be older than the osseous.

In some of the carnivora there are rudimentary pouch or marsupial bones, showing the relationship between these animals and the marsupials. In the latter, these bones are useful to support and protect the stomach and intestines against the pressure of the young in the pouch in which the young are carried by the mother. It is remarkable that the males of kangaroos and other marsupials also have the marsupial bones, without any pouch, however.

Probably the marsupial bones are the remains of a pelvic or belly bone belonging to the pelvic arch, and corresponding to the sternum or breast bone of the pectoral arch. (See chapter on osseous system.)

The rudimentary tails of men and apes have already been mentioned. Hoffman's sloth also has the same sort of a rudiment not showing itself outside of the skin. (Encyclopedia B-821).

In all birds the left ovary produces all the eggs, while the right one is aborted and becomes a useless rudiment.

According to Hæckel, it is proved by comparative anatomy and other means, that all dragon-flies, grasshoppers, beetles, bees, bugs, flies, butterflies, and other insects now living, have originated from a common ancestry having two pairs of wings and three pairs of legs. But a great many living insects are destitute of one or both pair of these wings, or have them in an aborted and functionless condition. Parasitic insects, especially, have, in most cases, lost both pair of wings—evidently because they ceased to use them.

The gill arches of the embryo are a necessary development in fishes, &c., but not in mammals. The gills in fish oxydize the blood, but they do not in the mammal embryo. Obviously they cannot and don't need to. Nature blindly makes these gill arches with their blood vessels and the blood going through them *as if* to be oxydized, and then in each case, as if finding out by actual experiment that they will not answer the purpose, they are torn down and new work substituted. Does this look much like intelligent design?

The rapidity of these early transitions show first the great frequency of their occurrence in the past, by which the ancient habits of develop-

ment have become so persistent, and, second, indicate the manner in which the short cuts of nature's work are accomplished. Two movements or processes follow each other, at first slowly, then, as facility is acquired, more rapidly and more rapidly till the two become simultaneous, blend into one, and become a compound process—as two sounds may be repeated alternately yet so rapidly as to be confounded as one to the human sense, and two colors the same; so in development, two or a dozen steps may be taken in such rapid succession as to evade human sense, or still more rapidly so that the two or dozen *are* only one.

It is undoubtedly true that five digits is the normal number for the vertebrates, from the amphibians up to man, but in the great majority an exception is made by the loss of one or more digits on either the fore or hind limb.

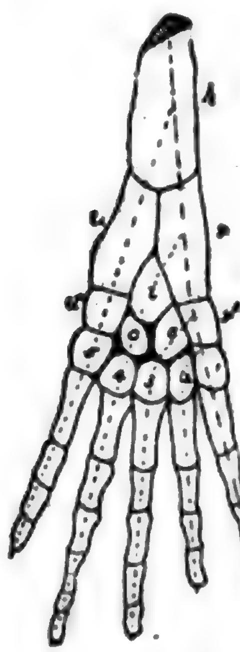


FIG. 68.

FIG. 68.—*Bones of fore limb of an amphibian* (frog &c).
h.—Upper arm, *humerus.*
r u.—*Radius* and *ulna* of the forearm.
r′ u′ c c i 1 2 3 4 5.—Root bones of the hand.
r′.—Radial.
u′.—Ulnary.
i.—Intermediate.

FIG. 69.—*Skeleton of right fore foot or hand of—I man, II dog, III pig, IV ox, V tapir, VI horse.*

r.—Radius } Bones of fore-arm.
u.—Ulna }

a.—Scaphoid.
b.—Semilunar
c.—Cuneiform
d.—Trapezium
e.—Trapezoid.
f.—Magnum.
g.—Unciform.
p.—Pisiform.
} bones of wrist.

1.—Thumb.
2.—Index.
3.—Middle finger.
4.—Ring finger.
5.—Little finger.

The horse has lost all his digits except the middle finger, on which he walks. The ox has two, the pig two useful and two rudimentary ones. (After Gegenbauer.)

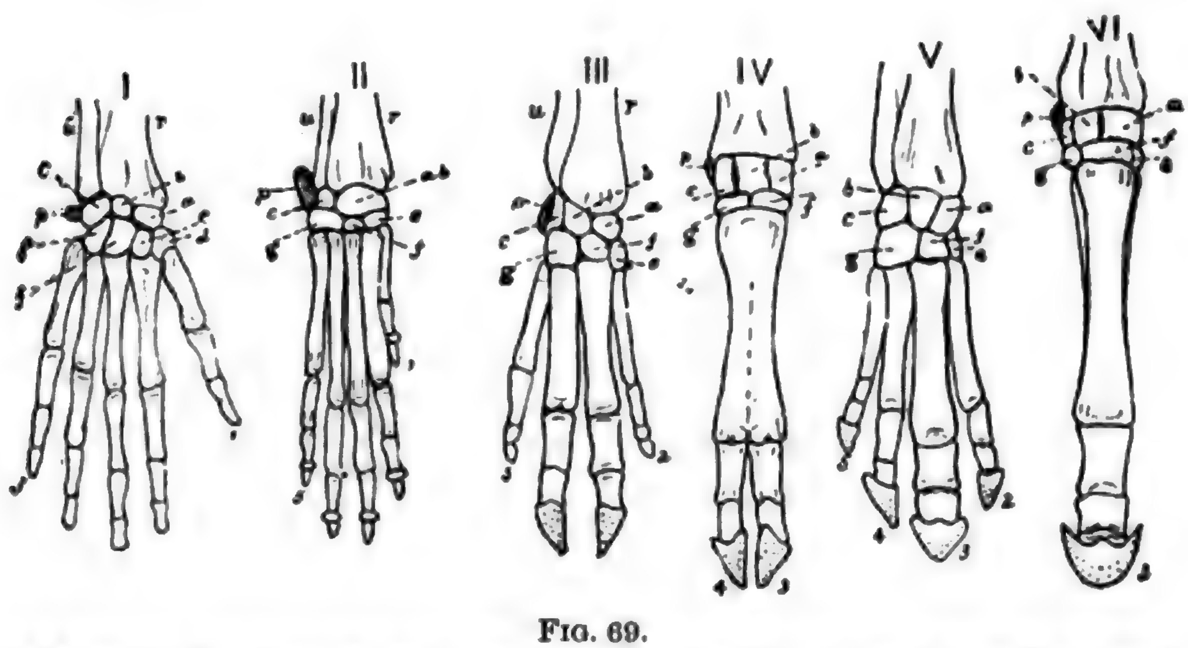


FIG. 69.

Originally the five-toed animal was a plantigrade, the entire hand or foot being placed on the ground in walking. But in the struggle for

existence, speed, either in escape or pursuit, must always have proved a winning quality, and consequently a subject of selection. Those animals which raise themselves off their heels and run on their toes, increase the length of their legs and consequently their speed. The changes brought on by the adaptive stimulation of the environment and natural selection, gradually raised the heel higher and higher, and at the same time brought the longer middle toes into more exclusive use, developing them excessively, and tending to abolish the shorter outside ones by depriving them of functional activity. Fig. 69 shows the loss of one digit, the thumb, in the case of the pig, while two others, the 2nd and 5th, are of no use and have become too short to touch the ground. The ox has lost his thumb. His index and his little finger are reduced to little rudiments which hang on behind, and he walks on his middle finger and "ring finger." The horse has lost all except the middle finger. The metacarpal bones which formerly supported his index and ring fingers, have long been useless and have almost disappeared, too, but a splinter on each side of the middle carpal bone still remains as their representative. See further on the history of the horse, in chapter 13.

In the genus *lialis* of the lizzard family, there are no fore limbs, and consequently no use for the shoulder bones. It has, however, rudiments of cartilage, representing the shoulder blade and collar bone, also a useless cartilaginous breast bone, which does not articulate with any ribs. This animal has inherited these relics of members which were in use amongst its remote ancestors, but which the changed habits of his immediate ancestors and himself have rendered useless. Other snake-like lizzards, as the blind worm (anguis) and the sheltopusik, are reduced in the same way.

Squirrels have five toes in the hind but only four in the fore feet with an additional tubercle representing the thumb. They hold their nuts between these tubercles when gnawing.

The sharks and rays possess rudiments of the air bladder, showing their ancestors, the early selachians, to have had it.

Darwin remarks: "rudimentary organs may be compared with the letters in a word, still retained in the spelling but become useless in the pronunciation, but which serve for a clew in seeking for its derivation."

As we go on we shall have occasion to point out numerous additional examples of retrograde adaptation and persistent rudiments, the relics of old time organs now long gone out of fashion.

CHAPTER VI.

TABULAR REVIEW.

The tables introduced in this chapter are from Hæckel's "Evolution of Man." They show in a comprehensive manner the general facts as to the status of man and the other animals, with relation to each other. Such tables are very handy to the student, for reference.

The pedigree tables must be regarded as to a certain degree provisional and tentative. But they are not likely ever to be altered in respect to main and essential points. In some minor points, no doubt, the progress of discovery has already prepared the way for revision.

In *Table I* we have a revised general classification of the *Animal Kingdom* based on their relationships of common derivation; according to Hæckel. The figures in the right hand column indicate the steps which are successive as to time, and correspond approximately with the steps indicated in Table IV. The figures in the middle column descend to particulars and indicate relationships corresponding with the distance apart of the numbers. Thus birds and mammals occupy the relationship of cousins; not that of a parent and child.

Table II is a classification of the *Vertebrate tribes*, according to their genetic relationships. There are two general divisions, the acrania or those without skull—comprising the single class amphioxida or lancelets, and the craniota or skulled animals, embracing all the rest of the vertebrates. These are again subdivided into those having only one nostril, embracing the hags and lampreys, and those having two nostrils.

This double nostrilled division is subdivided into six classes, three of which, the fishes, mud-fishes and amphibians, are non-amnionate, that is, not nursed in an amnion sac while in embryo, the other three, reptiles, birds and mammals, are amniota, their young being enclosed in an amnion sac during embryo life.

Table III is a like classification of *Mammals*. The lowest two subclasses—the monotremes and marsupials, while being amnionate are non-placental, all the higher tribes of the mammalia being placental. The placentals are seen to be divided into those *not deciduate*, those having *deciduate girdle* placenta and those having *deciduate discoid* placenta, distinctions which have been already explained.

In *Table IV* is given a progressive list of animal stages, from the bottom in monera to the top in man. There are twenty-two stages given. The differentiation of animal types, one from another, has been an infinitely slow process, and the steps have been inconceivably small. Animal types have attained their differences by the slow and gradual accumulation of such small differences as we can see between the brothers and sisters of any family. The tendency to inherit from ancestors, is

strong but not exact, and is satisfied with a general imitation, not insisting on all minute details. Or, to express it more scientifically, the law of inheritance tends to, and under *like conditions* of environment always will, produce exact copies, but because the like conditions of environment never do, and, in the nature of things, never can exist, therefore no generation is, or ever can, be an exact copy of its predecessors. Natural selection intervening, designates whether any modification thus made shall be perpetuated and intensified by further accretions in the same direction, or be suppressed. The table to be complete should contain a million terms instead of twenty-two. It is impracticable, of course, to construct such a table, and probably always will be. The stages represented in the table are to be regarded as the centers of wide districts, the borders of which are not sharp boundary lines, but which fade from one to another by so gradual a process that no boundary can be fixed. If we had all the inhabitants of a village collected in a body, and should then try to select out, by means of their family resemblances, those related to each other, we should undoubtedly get things mixed. If the population were of different races, we could easily enough pick out the full-blooded Africans from the full-blooded whites. The table is constructed something on this plan. The great and obvious successive terms are here; but the filling, which makes *one life* to extend generation after generation, individual by individual, from the monera and away beyond—for he is not the beginning of life—down to the brainy Caucassian, is all left out. The column on the right shows the types now living that most *resemble* the ancestral stages in the opposite column. It does not follow from this that the tribes on the right have stood still ever since our ancestral line was equivalent to what theirs is now. But supposing them to be subject to modification as we are, it follows that their ancestors were also ours, say ten million years ago, and a far lower type than they are now, but that *our* branch of the family reached the development in say five million years, the equivalent of which the other branch has taken the whole ten million for. This very obvious reflection amply accounts for the fact that some stages, which our line *must* have passed through, have no exact counterpart now living. Thus the fifteenth stage was the first race that developed the amnion sac. And we feel morally certain that from such a race all the reptiles, birds and mammals have descended, diverging from each other through lapse of time and changes of environment. But none of the descendants now living are exactly like that common ancestor. It is no wonder. Philologists assure us that the long list of languages named the Indo-European, and embracing as general divisions, the Celtic, Greek, Latin, Sanscrit, Persian, German, Sclavonic and Scandinavian, and whose sub-divisions run into hundreds of dialects, and are spoken

by diverse nations and tribes, are all derived from some common ancestral tongue. And all admit that that ancient tongue was very different from any of its surviving descendants—as different as they are from one another.

Language in its changes keeps pace with and is an indication of changes going on in the race that uses it. So, adopting precisely the same sort of logic, and with an equally positive assurance, the naturalist asserts that a tribe, in form something between a water newt and an ornithorhynchus, and bearing its embryonic young in a more or less perfectly developed amnion sac, existed about the beginning of the secondary geological epoch, and from it all the tribes of reptiles, birds and mammals have since descended.

Table V is a general family tree of the whole Animal Kingdom. There are two grand divisions—the Protozoa, which propagate by fission and never have eggs, and the Metazoa, which always have eggs. Another notable point here is that the worm tribe is common parent to the highest four great tribes or sub-kingdoms, the echinodermata, articulata, molluska and vertebrata.

Table VI is a like pedigree of the Vertebrata, beginning with the worms.

Table VII is the pedigree of Mammals, beginning with the monotrema.

Table VIII is the pedigree of the Ape tribes, beginning with the semi-apes (lemurs, &c.) and ending with Man. Man is not derived from any ape tribe now in existence, but from some ancient family of Asiatic apes which happened to enjoy a condition of life more favorable for advancement than that possessed by the rest. This family or tribe has received the title of *Alalus* or the *speechless*, which, I take it, is an extremely inappropriate name. I cannot imagine anything which would give a tribe or family more certain and permanent advantage over another one than a better ability by means of language to organize and combine for common and understood purposes. Most animals have a way of expressing general ideas to each other, and to that extent have a language. Many of the apes of the present day have very fair ability in that direction, and I have no doubt that the most distinguished advantage of the tribe of man-like apes that set up to be ape-like men and start the human race, was a better gift of language. This ancestor, then, should be called *Eulalos*, "good talker," instead of *Alalus*. His descendants to-day would be little better off than their cousins the gibbons, if they had no better language than they. Of course this "good talker" was good only by comparison with his own times, not ours.

In *Table IX* we have the four general stages of organ development from the original form in which each organ first occurs in the animal body, and its subsequent general modifications. Thus the skin system

begins in the gastreads or sac shaped animals as a simple outside skin —the exoderm. The intestinal system begins with the same animals as the entoderm, a simple inside lining of the outer sac. In the worms, however, the outer skin has developed into a double skin, and the inner skin or lining has also formed itself into two. In the mammals the outer skin develops hairs and glands. In the chorda animals (ascidians &c.) the respiratory and digestive apparatus are developed from the entoderm. So, also, the nervous system first appears in the primitive worms as a throat ganglion. In the chorda animals it becomes a simple medullary tube, while in the monorhina, such as lampreys, hag fish, &c., it expands to a brain and spinal marrow. The blood and lymph vascular system first occurs as a simple space or cœlom between the inner skin and the outer skin in the scolecida or soft worms. In the worms the dorsal and ventral blood vessels are differentiated in this body cavity—one above and the other below the primitive intestinal tube, &c., &c.

Table X shows the origin of the chief organ systems as they occur in the human body, which is, of course, typical of the mammalian class. The column on the right indicates the particular layers of the germ shield involved in the production of the organ opposite. Thus it can be seen at a glance that the "skin sensory layer" forms the epidermis, and is involved in the development of the brain and spinal marrow and brain nerves, all the organs of sense, touch, taste, smell, sight, and hearing; the genitals and probably the kidneys. The skin fibrous layer, or second membrane, is concerned in the leather skin, brain, spinal and intestinal nerves, the sense organs, the muscles and skeleton, the blood vessels, kidneys and reproductive organs. The third or intestinal fibrous layer is concerned in the formation of the sympathetic nerves, the digestive and respiratory systems, the vascular system and heart, the urinary bladder and the ovary. The fourth or intestinal glandular layer is concerned in the production of the intestinal tube and its appurtenances—the digestive and respiratory organs, the urinary bladder and probably the ovary.

TABLE I.—Systematic Survey of the Phylogenetic System of the Animal Kingdom founded on the Gastræa Theory and the Homology of the Germ Layers.

Tribes or Phyla of the Animal Kingdom.	Main Classes or Branches of the Animal Kingdom.		Classes of the Animal Kingdom.	Systematic Names of the Classes.		
	First Sub Kingdom *Protozoa.* Animals without Germ Layers, Intestines or True Tissues					
A Protozoa	I. Egg Animals (*Ovularia*)	1	Monera	1 *Monera*		1
		2	Amœbæ	2 *Lobosa*		2
		3	Gregarinæ	3 *Gregarinæ*		3
	II. Infusorial Animals (*Infusoria*)	4	Sucking Infusoria	4 *Acinetæ*		
		5	Ciliated "	5 *Ciliata*		4
	Second Sub-Kingdom—Intestinal Animals. (*Metazoa.*) Two Primary Germ Layers, Intestines and Tissues.					
B Plant Animals (Zoophytes	III. Sponges (*Spongiæ*)	6	Prim. Intestinal Animals	*Gastræada*		5
		7	Sponges	*Porifera*		
	IV. Sea Nettles (*Acalephæ*)	8	Corals	*Coralla*		
		9	Hood jellies	*Hydro Medusæ*		
		10	Comb-jellies	*Ctenophora*		
C Worms (Vermes)	V. Bloodless Worms (*Acœloma*	11	Primitive Worms	*Archelminthes*		6
		12	Flat Worms	*Plathelminthes*		7
	VI. Blood Worms (*Cœlomati*)	13	Round Worms	*Nemathelminthes*		
		14	Arrow Worms	*Chætognathi*		
		15	Wheel Animalcules	*Rotatoria*		
		16	Moss-Polyps	*Bryozoa*		
		17	Mantle-Animals	*Tunicata*		8
		18	Acorn Worms	*Enteropneusta*		
		19	Star Worms	*Gephyrea*		
		20	Ringed Worms	*Annelida*		
D Molluska	VII. Headless Shell Fish (*Acephala*)	21	Lamp Shells	*Spirobranchia*		
		22	Mussels	*Lamellibranchia*		
	VIII. Headbearing Shell Fish (*Encephala*)	23	Snails	*Cochlides* { *Gasteropod* / *Pteropod*		
		24	Cuttles	*Cephalopoda*		
E Star Animals (Echinodermata)	IX. Ringed Arms (*Colobrachia*)	25	Sea Stars	*Asteridæ*		
		26	Sea Lillies	*Crinoidea*		
	X. Armless (*Lipobrachia*).	27	Sea Urchins	*Echinida*		
		28	Sea-Cucumbers	*Holothuriæ*		
F Articulated (Arthropoda)	XI. Gill Breathers (*Carides*)	29	Crabs	*Crustacea*		
	XII. Tube Breathers (*Tracheata*)	30	Spiders	*Arachnida*		
		31	Centipedes	*Myriopoda*		
		32	Flies	*Insecta*		
G Vertebrata	XIII. Skull-less (*Acrania*).	33	Tube-hearts Lancelets	*Leptocardia*		9
	XIV. Single-nostrilled (*Monorhina*)	34	Round-mouths Lampreys)	*Cyclostoma*		10
	XV. Amnion-less (*Anamnia*)	35	Fishes	*Pisces*	Double-Nostrilled.	11
		36	Mud Fish	*Dipneusta*		12
		37	Amphibians	*Amphibia*		13, 14
	XVI. Amnion Animals (*Amniota*)	38	Reptiles	*Reptilia*		15
		39	Birds	*Aves*		
		40	Mammals	*Mammalia*		16 to 22

TABLE II.—Systematic Survey of the Phylogenetic Classification of Vertebrates.

I. Skull-less (*Acrania*) or Tube-hearted (*Leptocardia*) Vertebrates, without a Specialized Head, Skull, Brain or Centralized Heart.

1 Skulless *Acrania*	Tube-hearted Leptocardia	1	Lancelets	*Amphioxida*

II. *Animals* with Skulls (*Craniota*) and with Centralized Hearts (Pachycardia), *Vertebrates* with Specialized Head, with Skull and Brain, and with a Centralized heart.

Main Classes of the Skulled Animals.	Classes of the Skulled Animals		Sub-Classes of Craniota	Systematic Name of Sub-Classes
2 Single Nostrils *Monorhina*	II. Round Mouths (*Cyclostoma*)	2	Hags or Mucous Fish	*Hyperotreta* (*Myxinoida*)
		3	Lampreys	*Hyperoartia* (*Petromyzontia*
3 Non-Amnionate *Anamnia*	III. Fishes (*Pisces*)	4	Primitive Fish	*Selachii*
		5	Ganoid Fish	*Ganoides*
		6	Osseous Fish	*Teleostei*
	IV Mud Fishes (*Dipneusta*)	7	Single Lunged	*Monopneumones*
		8	Double Lunged	*Dipneumones*
	V. Batrachians (*Amphibia*)	9	Mailed Batrachians	*Phractamphibia*
		10	Naked Batrachians	*Lissamphibia*
4 Amnion Animals *Amniota*	VI. Reptiles (*Reptilia*)	11	Lizzards	*Lacertilia*
		12	Snakes	*Ophidia*
		13	Crocodiles	*Crocodilia*
		14	Tortoises	*Chelonia*
		15	Sea Dragons	*Halisauria*
		16	Dragons	*Dinosauria*
		17	Flying Reptiles	*Pterosauria*
		18	Beaked Animals	*Anomodonta*
	VII. Birds (*Aves*)	19	Longtailed	*Saururæ*
		20	Fantailed	*Carinatæ*
		21	Bushtailed	*Ratitæ*
	VIII. Mammals (*Mammalia*)	22	Cloacal	*Monotrema*
		23	Pouched	*Marsupialia*
		24	Placental Animals	*Placentalia*

TABLE III.—Phylogenetic Classification of Mammals.

I 1st Sub-Class Mammals	Cloacal Animals (*Monotrema* or *Ornithodelphia*)	1 Primitive Mammals 2 Beaked Animals		*Promammalia* *Ornithostoma*
II 2d Sub-Class Mammals	Pouched Animals (*Marsupialia* or *Didelphia*)	3 Herbivorous Pouched Animals 4 Carnivorous " "		*Botanophaga* *Zoophaga*
III 3d Sub-Class Mammals Placental Mammals *Placentalia* or *Monodelphia*	III (a) Placental Mammals without Decidua, with Tufted Placenta (*Indecidua Villiplacentalia*)	5 Hoofed Animals (*Ungulata*)	Single Hoofed Double Hoofed	*Perrisodactyla* *Artiodactyla*
		6 Whale-like Animals (*Cetomorpha*)	Sea Cows Whales	*Sirenia* *Cetacea*
	III (b) Placental Mammals with Decidua, with Girdle Placenta (*Deciduata Zenoplacentalia*)	7 Pseudo-Hoofed Animals (*Chelophora*)	Rock Conies Elephants	*Lamnunnia* *Proboscidea*
		8 Beasts of Prey (*Carnassia*)	Land Beasts of Prey Marine " "	*Carnivora* *Pinnipedia*
	III (c) Placental Mammals with Decidua, with Discoid Placenta, (*Deciduata Discoplacentalia*)	9 Semi-Apes (*Prosimiæ*)	Fingered Animals Long-footed " Flying Lemur Lemurs	*Leptodactyla* *Macrotarsi* *Ptenopleura* *Brachytarsi*
		10 Gnawing Animals (*Rodentia*)	Squirrel Species Mouse " Porcupine " Hare "	*Sciuromorpha* *Myomorpha* *Hystrichomorpha* *Lagomorpha*
		11 Toothless (*Edentata*)	Digging Animals Sloths	*Effodientia* *Bradypoda*
		12 Insect Eaters (*Insectivora*)	With Cæcum Without Cæcum	*Menotyphla* *Lipotyphla*
		13 Flying Animals (*Chiroptera*)	Flying Foxes Bats	*Pterocynes* *Nycterides*
		14 Apes (*Simiæ*)	Flat Nosed Narrow Nosed	*Platyrhinæ* *Catarhinæ*

TABLE IV.—Systematic Survey of the Most Important Stages in the Animal Ancestral Life of Man.

Epochs of the Organic History of the Earth	Geological Periods of the Organic History of the Earth	Animal Ancestral Stages of Man	Nearest Living Relatives of the Ancestral Stages
I Archilithic or Primordial Epoch	1 Laurentian 2 Cambrian 3 Silurian	1 Monera (*Monera*)	Protamœba
		2 Oldest Amœba	Simple Amœba (*Autamœba*)
		3 Amœboid Societies (*Syn-Amœbia*)	Morula Larvæ
		4 Ciliated Planulæ (*Planæadæ*)	Blastula Larvæ
		5 Primitive Intestinal Animals (*Gastræadæ*)	Gastrula Larvæ
		6 Primitive Worms (*Archelminthes*)	Gliding Worms (*Turbellaria*)
		7 Soft Worms (*Scolecida*)	? Between the Gliding Worms and the Sea Squirts
		8 Chorda Animals (*Chordonia*)	Sea Squirts (*Ascidiæ*) (*Appendicularia*)
		Boundary Between Vertebrate and Invertebrate	
		9 Skull-less (*Acrania*)	Lancelets (*Amphioxi*)
		10 Round Mouths (*Cyclostomi*)	Lampreys (*Petromyzontia*)
		11 Primitive Fishes (*Selachii*)	Sharks (*Squalacei*)
II Paleolithic or Primary Epoch	4 Devonian 5 Coal 6 Permian	12 Mud Fishes (*Dipneusta*)	Mud Fish (*Protoptera*)
		13 Gilled Amphibia (*Sozobranchia*)	Siren (*Proteus*) and Axolotl (*Siredon*)
		14 Tailed Amphibia (*Sozura*)	Water Newt (*Triton*)
III Mesolithic or Secondary Epoch	7 Triassic	15 Primitive Amniota (*Protamnia*)	? Between Tailed Amphibians and Beaked Animals
	8 Jurassic	16 Primitive Mammals (*Promammalia*)	Beaked Animals (*Monotrema*)
	9 Chalk	17 Pouched Animals (*Marsupialia*)	Pouched Rats (*Didelphys*)
IV Cenolithic or Tertiary Epoch	10 Eocene 11 Miocene 12 Pliocene	18 Semi-Apes (*Prosimiæ*)	Lori (*Stenops*) Maki (*Lemur*)
		19 Tailed Narrow-Nosed Apes	Nose Apes Holy Apes
		20 Menlike Apes or Tailless Narrow-Nosed Apes	Gorilla, Chimpanzee, Orang, Gibbon
		21 Speechless Men or Ape-like Men	Cretins or (*Microcephali*)
V Quarternary Epoch	13 Diluvial 14 Alluvial	22 Men Capable of Speech	Australians and Papuans

TABLE V.—Monophyletic Pedigree of the Animal Kingdom founded on the Gastræa Theory and the Homology of the Germ Layers.

Metazoa—Intestinal Animals. Two Primary Germ Layers, Exoderm and Entoderm. Intestine Enclosed by Entoderm.	Have Intestines, Cœlom and Blood.	VERTEBRATES.	Articulates. Mollusks. Echinoderms.
		CŒLOMATI (*Worms with body cavity*).	Flat Worms.
		ACŒLOMI.	
	No Blood or Body Cavity, Cœlom.		Sponges. Sea Nettles (*Acalephæ*).
		PROTHELMIS.	
			Protascus.
		GASTRÆA BILATERALIS (*Crawling*).	Gastræa radialis (*Stationary*).
		GASTRÆA—*Gastrula*.	Acinetæ. Ciliata.
Protozoa. No Germ Layers. No True Intestine.		PLANÆADA—*Blastula*.	Infusoria. Gregarinæ.
		SYNAMŒBA—(*Morula*).	Amœbina.
		AMŒBA—*Cytula*.	
		MONERA—*Monerula*.	

TABLE VI.—Pedigree of Vertebrates.

	Birds (*Aves*).
MAMMALS (*Mammalia*).	Reptiles (*Reptilia*).
AMNION ANIMALS (*Amniota*).	
BATRACHIANS (*Amphibia*).	Mud Fish (*Protopteri*).
MUD FISH (*Dipneusta*).	Osseous Fishes (*Teleostei*).
	Ganoids.
PRIMITIVE FISHES (*Selachii*).	
	Lampreys Hagfish.
DOUBLE NOSTRILLED.	
	Round-Mouths (*Cyclostoma*).
SKULLED—SINGLE NOSTRILLED.	Tube-hearted (*Leptocardia*).
SKULL-LESS (*Acrania*).	Ascidians. Sea-barrels.
VERTEBRATES.	Tunicates.
CHORDA ANIMALS (*Chordonia*).	
WORMS (*Vermes*)	

TABLE VII.—Pedigree of the Mammals.

MAN (*Homo*).

MANLIKE APES (*Anthropoides*).

NARROW NOSED APES (*Catarhina*).

APES.

False Hoofed (*Chelophora*).

Rock Conies. Elephants.

Gnawing Animals (*Rodentia*).

Lemurs (*Brachytarsi*).

Toothless (*Edentata*)

Flying Lemurs.

Flying Foxes—Bats.

Long-footed (*Macrotarsi*).

Sea Beasts of Prey (*Pinnipedia*)

Land Beasts of Prey (*Carnivora*).

Insect Eaters (*Insectivora*).

Whales (*Cetacea*)

SEMI-APES (*Prosimiæ*)

Sea Cows (*Sirenia*).

DECIDUOUS ANIMALS *Deciduata*).

Whale Family.

Hoofed Animals (*Ungulates*) (*Indeciduata*).

PLACENTAL ANIMALS (*Placentalia*).

POUCHED ANIMALS (*Marsupials*).

Beaked Animals (*Ornithostoma*).

PRIMITIVE MAMMALS.

CLOACAL ANIMALS (*Monotrema*).

TABLE VIII.—Pedigree of the Apes.

MAN (*Homo*).

APE-LIKE MAN (*Alalus*).

Gibbon (*Hylobates*). Orang (*Satyrus*). Gorilla. Chimpanzee.

ASIATIC MAN-LIKE APES.

African Man-Like Apes.

MAN-LIKE APES (*Anthropoides*).

Sea Cat (*Cercopithecus*). Tall Ape (*Semnopithecus*). Nose Ape (*Nasalis*). Baboon (*Cynocephalus*).

Silk Apes (*Hapalida*). Clutch Tails (*Labidocerca*).

TAILED APES (*Menocerca*).

NARROW NOSED (*Catarhinæ*).

Flap Tails (*Aphyocerca*).

Flat Nosed (*Platyrhinæ*).

APES (*Simiæ*(.

SEMI-APES.

PROSIMIÆ.

TABLE IX.—Schedule of Most Important Animal Parts, with the Tribes in which they Probably First Appeared, in the Column on the Right.

1	Skin System	1 Simple Exoderm	Gastreads
		2 Outer Skin (Skin Sensory Layer) and Leather Skin (Skin Fibrous Layer)	Worms
		3 Outer Skin with Hairs, Glands, &c.	Mammals
	Intestinal System	1 Simple Entoderm	Gastreads
		2 Intestinal Epithelium (Intestinal Glandular Layer) and Intestinal Muscular Skin (Intestinal Fibrous Layer)	Worms
		3 Gill Intestine and Stomach Intestine	Chorda Animals
2	Nerve System	1 Upper Throat Ganglia	Primitive Worms
		2 Simple Medullary Tube	Chorda Animals
		3 Brain and Spinal Marrow	Monorhina
	Muscle System	1 Skin Muscle Pouch	Primitive Worms
		2 Side Muscles of the Trunk	Acrania
		3 Trunk and Limb Muscles	Fishes
3	Kidney System	1 Primitive Kidney Canals	Soft Worms Scolecida
		2 Segmental Canals	Acrania (?)
		3 Primitive Kidneys	Monorhina
		4 Permanent Kidneys	Protamnia
	Vascular System	1 Simple Cœlom	Scolecida
		2 Dorsal and Ventral Vessels	Worms
		3 Heart (Part of the Ventral Vessel)	Chorda Animals
		4 Heart with Auricle and Ventricle	Monorhina
4	Skeleton System	1 Simple Notochord	Chorda Animals
		2 Cartilaginous Primitive Skull	Monorhina
		3 Gill Arches, Ribs, Limbs	Selachii
		4 Limbs with Five Digits	Amphibia
	Sexual System	1 Simple Hermaphrodite Glands	Chorda Animals
		2 Distinct Testes and Ovaries	Acrania
		3 Seed duct and Oviduct	Selachii
		4 Phallus (Penis Clitoris)	Protamnia

TABLE X.—Organ Systems of the Human Body.

I. Indicates Derivation from Skin Sensory Layer.
II. " " " Skin Fibrous "
III. " " " Intestinal Fibrous Layer.
IV. " " " Intestinal Glandular "

Animal Organ System.	A Sensory Apparatus (*Sensorium*)	1 Skin Covering (*Derma*)	Outer Skin	*Epidermis*	I.
			Leather Skin	*Corium*	II.
		2 Central Nerve System	Brain	*Encephalon*	I.
			Spinal Marrow	*Medulla Spinalis*	I.
		3 Peripheric Nerve System	Brain Nerves	*Nervi Cerebrales*	I. and II.
			Spinal Nerves	" *Spinales*	II.
			Intestinal Nerves	*Sympatheticus*	II. and III.
		4 Sense Organs	Organ of Touch (Skin)	*Org. Tactus*	I. and II.
			Organ of Taste (Tongue)	" *Gustus*	
			Organ of Smell (Nose)	" *Olfactus*	
			Organ of Sight (Eye)	" *Visus*	
			Organ of Hearing (Ear)	" *Auditus*	
	B Motive Apparatus (*Locomotorium*)	5 Muscle System (Active Motor Organs)	Skin Muscles	*Musculi Cutane*	II.
			Skeleton Muscles	" *Skeleti*	
		6 Skeleton System (Passive Motor Organs)	Vertebral Column	*Vertebrarium*	
			Skull	*Cranium*	
			Limb Skeleton	*Sk. Extremitatum*	
Vegetative Organ System	C Nutritive Apparatus (*Nutritorium*)	7 Intestinal System (*Gaster*)	Digestive Organs	*Digestiva*	III. and IV.
			Respiratory Organs	*Respiratoria*	
		8 Vascular System (*Organa Circulationis*)	Body Cavity	*Cœloma*	II. and III.
			Lymph Vessels	*Vasa Lymphatica*	II. and III.
			Blood Vessels	" *Sanguifera*	
			Heart	*Cor*	III.
		9 Renal System (*Organa Urinaria*)	Kidney	*Renes*	I. (?) and II.
			Urinary Ducts	*Ureteres*	
			Urinary Bladder	*Urocystis*	III. and IV.
	D Reproductive Apparatus (*Propagatorium*).	10 Sexual Organs (*Organa Sexualia*)	Sexual Glands	*Gonades*	
			(I. Ovary)	(*I. Ovaria*)	III. and IV. (?)
			(II. Testis)	(*II. Testes*)	I. and II. (?)
			Sexual Ducts	*Gonophori*	I. (?) and II.
			(I. Oviduct)	*I. (Oviductus)*	
			(II. Seed Duct)	*II. (Spermaductus)*	
			Copulatory Organs	*Copulativa*	I. and II.
			(I. Sheath)	(*I. Vagina*)	
			(II. Penis)	(*II. Penis*)	

CHAPTER VII.

TESTIMONY OF GEOLOGY.

It will now be profitable to take a brief glance into geological history and see what that science has to reveal in regard to the relations of animals to their environment and to each other in the past. Two important questions come up in this connection. One is, has there been time enough in the past history of the earth for the evolution of the higher organic forms, as they are now, from the lower? The other is, do the geological records support the assumption that the lower forms have been succeeded, instead of preceded, by the higher?

It is generally conceded that the earth was formerly a melted mass, which has now become cool on the outside, but that the crust is as yet only a few miles thick. Since the crust began to form, the watery vapor which composed a part of the earth's mass has become condensed into water and run down into the lowest parts. The parts above water have been constantly exposed to the action of winds and rains, and in some parts to that of frost and ice, and in others to melting heat from the inside. These agencies have wrought great changes, especially in the erosion of the land and carrying it down to the sea where it has been spread out into strata. The cooling of the crust has been accompanied by changes in its form, due to unequal contractions, so that what has been sea at one time becomes land at another, and vice versa. So, material which in one age is torn from the land and piled away in the sea, may, in another age, be moved again to another place. The number of alternations between sea and land which have taken place in some parts of the world are very numerous. The crust of the earth is in constant movement, although it is on the whole exceedingly small. It is said there is an earthquake *somewhere* every day.

The expression, "everlasting hills," which we sometimes use, indicates our sense of the extreme slowness with which the hills are worn down and carried off by various dynamic agencies at work on them. If now we try to realize that these hills (if stratified) were made of other hills by a process as slow as that which is now at work, and reflect that this business has been going on long enough to carry away a total thickness of hills equal to about *twenty miles*, if we suppose them all in one place, we shall then begin to have some conception of the "everlasting" length of time.

The tables on pages 68 and 69 are intended to show the relative position and age of the different formations, together with their organic

remains. These are named in the first period in which they occur. The period of the extinction of some of them is also given. The greatest thickness of the strata is given, and there is an attempt to estimate the geological times in years. Dana estimates that the deposition of limestones as the remains of calcareous shells requires at least five times as long as the deposition of sedimentary rocks. On this basis the relative times of the Tertiary Mesozoic and Paleozoic would be nearly in the ratio of 1, 2, 4. The Mesozoic of Germany is composed as follows: Triassic, 1,000 feet limestone and 2,400 of sedimentary deposits, Jurassic, 1,000 feet limestone, 4,200 of sediments, Cretaceous, 1,200 feet limestone and 1,200 feet sediments. Multiplying the limestone by five in each case and adding the sediments to the products we get for the Triassic, 7,400, Jurassic, 9,200, Cretaceous, 7,200. These figures, therefore, represent the beds as if they were all sedimentary. From calculations based on the amount of sediment carried off by the Mississippi river, it is estimated that it denudes its whole basin at the rate of one foot in five thousand years. If it be assumed that the sediments are deposited over an area one-fourth as great as that from which they are taken, and that the erosion of the Mississippi valley is a fair average, it follows that rocks are built at the average rate of one foot in 1,250 years. Applying this rate to the Mesozoic of Germany we get nine and one-fourth millions years for the Triassic, eleven and one-half for the Jurassic and nine for the Cretaceous, or as stated in even numbers in the table, nine, twelve and nine millions respectively. The other ages are figured from this according to proportions above. The thickness of the Eozoic in Bohemia is 90,000 feet. Its age is estimated by the same rule in the table. The Canadian Eozoic is about 49,000 feet thick, but separated by a period of elevation, erosion and depression which would probably make its age as great as the European. The Quarternary time is assumed at half the Tertiary by some geologists, and so it is in the table. The Quarternary is an age of erosion, and such estimates as there are, have to be founded on the phenomena of denudation and erosion mostly. The formation of the great canyons and gorges in the Pacific states and western territories, and of the Mississippi and Niagara rivers, is all recent or Tertiary. It is estimated by Lyell that the Niagara gorge forms at the rate of one foot per annum. Desor put it at three feet in a century. Dana suggests one inch per annum which is doubtless nearer the truth than either of the other estimates. At this rate the formation of the gorge has already occupied 380,000 years. Now the grand canyon of the Colorado is on an average thirteen times as deep and it is about forty-three times as long as the Niagara gorge, and if the conditions of erosion were equal, the Colorado canyon would be 212,420,000 years old—if the Niagara is 380,000. But the conditions seem to have been in favor of the Niagara,

for the quantity of water in the Colorado is less, the rock is much harder and the fall per mile is much less. Moreover, Powell shows that the river runs *across* the anticlinal ridges and synclinal valleys, which proves that the elevation of these ridges was so slow that the river had time to cut its way across them faster than they rose. Otherwise it would have been diverted from its course and compelled to traverse one of the synclinal valleys. This cutting has been very slow and the work began a very long time ago. And yet it certainly began since the Jurassic times, and probably since the Cretaceous. Since the estimates of the table are only one-ninth to one-sixth as much as this canyon gives, they may be considered moderate. The proofs of age drawn from other gorges, and from continental erosions are equally conclusive.

The spaces between many of the formations indicate pause in rock building, ordinarily accompanied with oscillations or changes of level, often of the most radical character and consuming vast periods of time. No correct idea of geological history or of the history of evolution can be got without some understanding of these pauses. Their duration is largely conjectural, but can sometimes be reduced within probable limits. Where one series of rocks rests upon another in unconformity, it proves that the lower series has been tilted up, more or less eroded and then sunk below the sea to receive the top series, because when first laid down, all sedimentary rocks are practically level. If the number of feet of erosion can in any case be estimated, the table multiplies that number by 5,000, as the number of years required to erode one foot, using the Mississippi again as the average, and taking no account of the time occupied in bringing the lower series to the top of the water after its first accumulations cease, or sinking it *below* the water before its second accumulations commence.

These tables make the time since the beginning of the Laurentian, 289,500,000 years. The estimate, I have no doubt, is many times too conservative. That of Volger is 648,000,000.

Time is long; and enough has elapsed for all the requirements of the construction of plants and animals from the mineral materials.

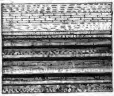
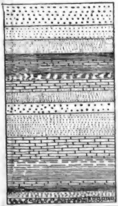
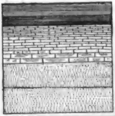
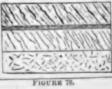
Times	Ages	Periods	Thickness Feet	Years	Strata	Organic History
Long period of disturbance during which the Appalachian and other regions were elevated, largely denuded and some of them sunk again to receive the Mesozoic deposits.						
Paleozoic	Carboniferous—Age of Coal Plants.	Permian	14,700	7,000,000		End of Trilobites, Goniatites, Eurypterids and Productus Proterosaurus.
		Carboniferous				Labyrinthodonts Sauroid Fishes Scaled Amphibians Hybodont Sharks Snails Myriapods Ferns Conifers Limuloids *Macrourans* Insects Orthopters and Arachnids Lycopodia
		1000 Feet Denudation			5,000,000 Years	Unconformability
		Sub-Carboniferous	6,000	5,000,000		Cestraciont Sharks (Cladodus, &c.) Reptile Tracks (Amphibian) End of all the old genera of Trilobites
		1,000 Feet Denudation			5,000,000 Years	
	Devonian—Age of Fishes.	Catskill	14,400	12,000,000		Holoptychius (Ganoid) *Telerpeton* Salamandroid Amphibian
		Chemung				No Vertebrates Few New Shell Fish Noeggerathia (Sea Weed) Calamites
		Hamilton				Insects (Neuropters), Goniatites (Ammonites), (No Vertebrates), Lepidodendron and Sigillaria
		Corniferous				Pterichthys (Ganoid), Selachians, Ganoids, Pentremites (Crinoids), Productus, Cauda Galli (Sea Weeds) Desmids
		Oriskany				New Species End of Cystids
	Silurian—Age of Mollusks. Upper	Helderberg	7,200	7,000,000		Eurypterus remipes (Crustacean) Tentaculites
		Salina				Few New Species
		Niagara				Brachiopod Pentamerus (Ormoceras ends), New Fucoid Rusophycus Bilobatus
Period of elevation and denudation to the amount of 2,000 feet, requiring 10,000,000 years. 2,250 species become extinct.						
	Lower	Hudson	14,800	29,000,000		New Species of Those Below
		Trenton				Nautilus, Cryptoceras, Starfish, Ormoceras, Cyrtoceras, Cystids, Corals, Maclurea
		Potsdam				Bryozoans, Conchifers, Ostracoids, Orthis, Rhynconella, Lituites, Orthoceras, Trilobite, Marine Gasteropod, Lingula Pteropods, Worms, Discina, Crinids, Graptolites Sponges and Rhizopods Fucoid Sea Weed
Interval, in which the Eozoic rocks were raised slowly out of the water, planed off 6,000 feet, and sunk again to receive the Silurian deposits. (6,000 x 5,000) 30,000,000 years.						
Eozoic	Dawn of Life	Huronian	18,000	90,000 112,000,000		Graphite Eozoon
		Laurentian	21,000			Iron Ore Deposits Algæ
Azoic	Age of Fire					

FIGURE 70.

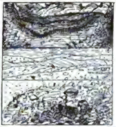
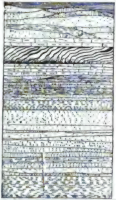
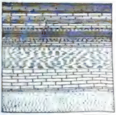
Times	Ages	Periods	Thickness Feet	Years	Strata	Organic History
Cenozoic.	Quarternary.	Terrace		7,500,000		
		Champlain				Man, Ass, Dog
		Glacial				Bison, Stag, Beaver Equus, Elephant, Hog Racoon, Wolf, &c.
		During the Tertiary a further elevation and denudation of Utah and Rocky Mountain region, and further sinking of Pacific Ocean, both coming to the present time. Great sheets of lava flowed from the Sierras, covering 150,000 square miles, some places 4,000 feet thick, at the end of the Tertiary and during Pliocene.				
	Tertiary—Age of Mammals	Pliocene	8,000	15,000,000		Pliohippus, Oreodon Pithecus Semnopithecus, Phoca (Seal) Protohippus, Hipparion Great Lava Flow. Formation of Pacific Coast Chain
		Miocene				All Orders of Insects Monkeys, Rhinoceros Hippopotamus Mesohippus, Tiger Amphistegina replaces Nummelites
		Eocene	3,000			Placental Mammals, Tapir Lemur, Marmosets, Elephant and Mammoth-like Animals, Bear, Camel Cetaceans Eohippus, the First Horse Snakes Oak, Fig, Palm, &c Bats, Opossums Nummelites (Rhizopods)
		Elevation of the Rocky and Wahsatch Mountains above water. Elevation of the Mississippi Valley, abolishment of the internal sea of North America, and formation of lakes in the West. No species have survived this age of oscillation. Unconformity in Europe. Time (3,000 x 5,000), 15,000,000 years.				
Mesozoic	Age of Reptiles.	Cretaceous	2,400 Germany 20,000 Pacific	9,000,000		End of Ammonitidæ Wading Birds with Teeth Teliost Fishes, Ganoids, homocercal Angiosperms and Endogens begin
		Elevation of Sierra and Cascade Ranges probably simultaneous with the formation of the Cretaceous period. Sinking of the bed of the Pacific.				
		Jurassic	5,200	12,000,000		More Marsupials More Insects Great, Marine, Land and Flying Saurians Squalodont Sharks, Pterodactylans, Belemnites, Ammonites, More Marsupials.
		Triassic	3,000	9,000,000		First Mammal, a Marsupial Ceratodus Bird like Amphibians Beaked Saurians Lacertians Ceratites (Ammonitidæ) Cycads

FIGURE 71

CHAPTER VIII.

EOZOIC AGE.

PROTOPHYTES—FIRST PLANTS. } SUB-KINGDOMS.
PROTOZOA—FIRST ANIMALS. }

The lowest of animal forms is embraced under the title of *Sub-Kingdom Protozoa*, meaning *First Life.*

Some of the protozoans are fresh water and others sea water animals, and they may be found in moist places on land. Fig. 7 represents a moneron, and fig. 8 an amœba. The first is the simplest as it appears to be without a nucleus. The last is simply a minute mass of jelly in which there is a minute granule or nucleus, and it is enclosed in a sack called the *ecdosarc* or outside skin. This skin has about the consistency of a soap-bubble, and like it can be pierced without being destroyed. The animal gets its food, which consists of minute vegetables, such as diatoms and desmids, through this ecdosarc which closes up and repairs the breach. Effete matters are discharged in the same way. The animal is nothing but protoplasm, the outside of which is slightly differentiated into the ecdosarc, and it is without organs of any kind, not even a mouth or an alimentary canal. They propagate by *fission.* Their locomotion is by the expansion or pushing out of the edge of the body, first on one side then on another, and the contraction of the rest of the body toward the part pushed out. One side or end is just as good as the other for this purpose.

Another of these amœba-like animals is the *actinophrys.* This is a more defined and constant body than amœba, in this, that the same end generally goes first, and that the same certain parts of his body are likely to be moved to accomplish his locomotion. Otherwise he is apparently of as simple an organism as the amœba. Although such an animal, consisting of a bit of slightly modified vegetable protoplasm, was the first to exist, it is obvious that so soft and perishable a body could not be preserved as fossil.

The lowest fossils are, however, animals of a type but little, if any, higher than the amœba or actinophrys. They are called foraminifera or rhizopods, eozoa, &c. Each animal is a single cell covered with a thin shell of calcareous matter, which it deposits on its outside, and which remains after the soft parts of the animal have disappeared. Through this shell are minute holes (foramina) through which a part of the animal protrudes in minute waving fibres which are called "pseudopodia"—false feet. Sometimes these shells are attached together in masses of various shapes, each cell, however, remaining the house of a single simple animal.

The eozoa are the earliest forms of foraminiferous animals found fossil. Dr. Dawson shows that the eozoa grew in large masses and in various forms, in the upper part of the Lower Laurentian series of rocks. And he calls attention to the fact that far below the strata in which the eozoon is found, are vast beds of metamorphic limestone, in which the traces of animal life are destroyed, but which, without doubt, were entirely made up of the calcareous shells of these simple animals.

The Lower Laurentian rocks of Canada are about 35,000 feet in aggregate thickness, of which three limestone beds amount to 3,500 in thickness. There are also large quantities—in some places amounting to 20 to 30 feet in thickness—of carbon in the form of graphite—all of which, without doubt, is the product of vegetation, and shows that for untold ages before the beginning of the Silurian era—the first era credited with organic life, by the early geologists—simple forms of both animal and vegetable life flourished in immense abundance. In fact the world was an *old* world at the beginning of the Silurian age.

The total thickness of the series of metamorphic or Eozoic rocks of Canada, is not less than *six* miles, and in some places may reach *nine.* The same system, in some parts of Europe, has a thickness of 90,000 feet or *seventeen* miles.

Dr. Dawson's conclusions relating to the eozoon fossils, have been disputed in some quarters, it being held that the present state of the fossils is such that on account of the great heat they were subjected to in metamorphic times, no certain conclusion as to their origin is warrantable. Well, granting that the fossil itself is not sufficiently well preserved to be identified with certainty, there are those vast layers of limestone and graphite to be accounted for.

Dawson holds that there is no possible origin for the graphite except through vegetation, that there is no agency except plants that will disengage the oxygen from the carbonic acid. Dana holds the same view practically. In regard to the formation of the limestone strata Dana says there is only one way in which limestones can be formed in water, and that is by the wear and accumulation of shells of animals. The limestones of the Silurian and later ages have nearly all been made from crinoids, corals and the calcareous relics of other animals. He cites strata of the Silurian period, which are presumed to be composed of the remains of microscopic cells of rhizopod animals. If the limestones of the Silurian and later ages were made from shells, there is equal reason for supposing them to have originated in the same way in the earlier ages.

The rhizopod is of the same organic value as the eozoon of Dr. Dawson, and is, in fact, nothing more than a microscopial bit of protoplasm surrounded with a minute shell of limestone perforated with holes, through which the animal projects slender processes of his protoplasm,

and by means of which his accretions and excretions take place. He has no mouth, stomach or permanent members. Sometimes these animals live in families or communities, their shells being massed together in various forms, but in all cases each shell or cell contains a single simple one-celled animal. It is from the accumulations of the remains of this kind of animals that we are to presume the limestone beds of the Laurentian were formed, in all, two-thirds of a mile in depth. It is not probable that any orders of animals of much higher organization than these existed in America before the Silurian times.

The plants to which the origin of the graphite is attributed, were also of very simple organization. They were all algæ or sea weeds and of the lowest order. But they must have existed in immense quantities to form an amount of graphite equal to thirty feet in thickness. Dana estimates that a bed of bituminous coal requires for its formation not less than eight times its bulk of compact vegetable debris. And anthracite requires twelve times its bulk. Graphite would require much more still. So that it is safe enough to estimate that the remains of five hundred feet in depth of solid vegetable matter is represented in the Laurentian formations, beside what was turned back into carbonic acid in the fearful scorchings of the metamorphic ages—which in all reason must have been an enormous amount. It is assumed that all this vegetation consisted of algæ, for the reason that these plants are the simplest on earth, and that they are the only sort of vegetation to be found in the long Silurian ages following the Laurentian. They are the most versatile and hardy of all plants, can live on the rankest and rawest of mineral compositions and in the greatest variety and extremes of temperature. As these algæ, no doubt, furnish us with the earliest examples of plant life that we are acquainted with, it may be well to describe some of them. The simplest forms are the protophytes, the diatomaceæ and desmidiaceæ, or, for short, diatoms and desmids. These have but a single cell and are microscopical. Their mode of propagation is by fission. In the mature plant a partition is formed, the protoplasm contained in the case of the cell dividing into two parts, each part growing into a complete cell, when they become detached. The protococcus is of another order of algæ, and while only single celled like the diatom, differs in function. It has red coloring matter in it, and reproduces by its internal colored protoplasm forming into several separate spheres or spores. As these grow, in a few hours they burst the shell and escape. Many of these spores are carried everywhere by the air. They grow on rocks and in the snow in Greenland and Sweden, giving the snow a red color. They also grow in the Red Sea and give it its color. It is likely that these infinitesimal plants, through their very rapid reproduction, may have contributed toward

forming the carbon beds of the Laurentian times. Some of the diatoms surround themselves with shells of siliceous material, which are known to furnish a sufficient accumulation in places, to form layers of flinty stone. Nullipores and Corallines are simple plants that also form deposits of calcareous matter, which are known to contribute to the formation of limestone beds. There are many large forms of algæ, all, however, of very simple organic structure, some of which, chiefly fucoids, a leathery variety, are found in the Potsdam period. We are at liberty to conclude that the simplest forms of both animal and vegetable life existed for many long ages before the beginning of Silurian times.

CHAPTER IX.

SILURIAN—AGE OF MOLLUSKS.

Lower Silurian Age.

The lowest or earliest part of this age is called the Potsdam period. The only plant life in this age that made any record, consists of several varieties of the fucoid algæ. These are round stems, some thin, others as much as half an inch in diameter. The latest of them are branched varieties, yet they are all very simple in structure. They have no roots or leaves, but absorb their nourishment through their cell walls. No land plants are found and probably there were none But there must have been immense quantities of the sea-weed, because there were immense numbers of sea animals that depended upon it for support.

This animal life was, within certain limits, greatly varied. Of zoophytes there were sponges, graptolites and sertularians, and in the latter part of the period, corals. All these animals are single celled, living in aggregations or communities, and attaching cell to cell, after a pattern peculiar to each species. Most of them are like bushes or trees of various patterns.

Of worms there were a good many. The bodies of soft worms would obviously not be of easy preservation, and it may be taken for granted that many existed of which no vestige is left. "Impressions of long marine worms have been reported from some of the shales. Besides these, there are worm-holes in the Potsdam sandstones—though now filled with rock—which are referred to burrowing worms of the Arenicola family (so called from the Latin *arena*, sand, and *incola*, inhabitant). They penetrate the rock vertically, and are often in pairs, as is now the habit of such worms. The most common kind in the Potsdam sandstone is called *scolithus linearis*." (Dana 185.)

There were great numbers of brachiopods. These are a bivalve shell fish, classed generally as the lowest order of the mollusks, and are called molluscoids by some. In Hæckel's classification they are the *spiro-*

branchia. This little animal has a shell on its back and another on its belly, in which respect it differs from the clam tribes which have the shells on their flanks.

The shells of the brachiopod are not hinged, but at the hinge edge, which is the one opposite the mouth, a fleshy peduncle or stem protrudes between the edges of the shells or through a hole in one of them, by which the animal is fixed to a rock, mouth up.

The brachiopods are so called from their two spiral or coiled arm-like feet, which are attached at the sides of the mouth and can be protruded to collect food, and also act as gills. These arms are, in some families, furnished with fringes. Sometimes inside the shell there are loops or coils of calcified matter for the arms to rest in. They have a single nerve ganglion which probably acts to correlate the sense of touch in the arms. White blood circulates in the body cavity or cœlom. There are ten families of brachiopods. Two of these families, the Discina and Lingula, have representatives in the Potsdam period, and what is remarkable, one genus or another of each of these families, is to be found in all the great geological periods from that day to this, and they are still extant. New species and genera have constantly arisen as the old ones have died out, but the family type still persists.

There are two other families represented, the Orthis or Strophomena, and the Rhynchonella families. The former became extinct in the Lias, while some species of the latter still exist.

Of mollusks proper we have, in the Potsdam, first, Pteropods (wing-footed animals). They are minute in size, generally in a conical, spiral or two plated dorsal and ventral shell, though sometimes naked. They have a more or less distinct head, on each side of which is a wing-like appendage which operates like a fin, by which the animal swims. They are permanently just what the sea snails are in their larval state, from which it may be inferred that the sea snails are descended from the Pteropods. The Pteropods, under Hæckel's new classification, would come under class Cochlides.

The next division of Mollusks represented in the upper part of the Potsdam, viz., the Calciferous epoch, is the Gasteropod (or *belly foot*), so called because he projects his ventral muscle and moves on it—something like a foot. This class, and the Pteropods just spoken of, are designated as *Cephalates* or those having heads. They are divided into two sections: those breathing by means of gills, and those breathing air by means of lungs. Snails and slugs are examples of the latter. The fossil Gasteropods from the Potsdam formations, are, of course, of the gill-bearing section. Inside the shell the animal is enclosed in a mantle or loose skin, which is sometimes prolonged into a tube or siphon in front. The shell is generally spiral, like that of the snail. In some,

however, the shell is not all in one solid piece, but in eight transverse segments. Beginning at the front end, each segment is grown to the pallium or mantle by its forward margin, while its hinder margin laps over the segment or plate behind it. The Gasteropod had a toothed tongue and a heart. The heart may have only one chamber, a ventricle, which is the case with the *Natica*, one of the families represented in the upper Potsdam, or it may have two cavities, an auricle and a ventricle, sometimes near together, but often in different parts of the circulatory system, of which they constitute merely swellings or enlargements of the vessels.

The Turbinidæ, a family related to the Natica, is represented by the Trocus genus in the Potsdam. The Gasteropods also belong to Hæckel's Cochlides.

Next, and highest of the Mollusks, are the Cephalopods. To this class belong the modern Sepia or cuttle fishes, the Octopus or Devil fish, the Nautilus, and Loligo or squid. The Orthoceratidæ, the Belemnitidæ, and the Ammonitidæ are fossil and extinct. The Orthoceratidæ began in the Potsdam period, and disappeared in the Triassic. Some of the Nautilus family are also extinct, some beginning and ending in the Silurian age. The Orthoceras is like a *straight horn*, hence the name. It was a straight cylindrical or rather tapering shell, divided internally by cross partitions into a series of segments. A tube or siphuncle passed through all these partitions, from end to end of the animal. This siphuncle is, in some species, in the center, in others, dorsal or nearer the back, in others, ventral or in the lower part. The animal was composed of metamera, or sections, which were connected with each other through the siphuncle.

The modern cephalopods have eight or ten arms or tentacles arranged around the mouth, they have two or four plume-like gills within the mantle, they have an orifice in front under the mouth called the funnel (infundibulum), through which the effete matters are voided in their water respiration. They are all naked except some species of the Nautilus, but some have a calcareous or flexible, horny skeleton of simple structure, inside. They have eyes and nervous throat ganglia with nerve filaments running to the organs. Their circulation is kept up by the action of two or three contractile chambers connected with, or part of, the blood vessels—hearts.

It is impossible to determine just how much of this internal machinery was possessed by the ancient ortheceras and his relations. His circulatory and nervous systems, at least, were much simpler. His relatives of the family of the Orthoceratidæ differed from him chiefly in their external form, as they were curved like a horn in the Cyrtoceras, curved into a disc or flat scroll in the Gyroceras. These variations of form are,

doubtless, of minor signification. Their sizes are greatly varied. Some specimens in the Trenton period were fifteen feet long and nearly a foot in diameter.

There is one other class of Mollusks; viz., the Lamellibranchiata (plate gilled) or conchifers. They are also called *acephals* or headless mollusks, which only means the head is not distinct and separate, and they are also commonly known as bivalves. They are divided, by Carpenter, into twenty-one families. Living and dead, the species will run up into the thousands. They include the oysters, cockles, mussels, scallops, clams, &c. The mouth of the bivalve is at one end of the shell—the short end, the posterior part of the animal is at the long end, the shells are right and left, his back is against the hinge, and his belly at the open edge. On this side is his tough muscle, called the foot, on which he stands and by which he shoves himself along.

* A description of a fresh water mussel, Anodonta cygnea, will answer as a type of the Lamellibranch. The mantle or pallium almost envelops the rest of the body. Inside the mantle, on each side of the body toward the rear, are two gills (four in all). Between the gills, but forward of them, is the muscular foot. Above the foot, near the hinge, are the heart, stomach and other intestines. There is an orifice at the bottom, when the shell is open, called the inhalent siphon, into which water, laden with diatoms and other food, enters and passes on to the space about the gills. From there the water, after contact with the gills, passes out through the exhalent siphon, another orifice at the rear, while the food matters are swept forward to the mouth by cilia, which line the cavity. There is a gullet, a stomach, a long intestine which is coiled and doubled up a good deal, and passes through the pericardium and heart and finally reaches the rectum and anus.

The blood is colorless and contains colorless corpuscles which resemble those of man, and present the same amœbiform movements. There is a nervous system with three pairs of yellow ganglia—one in the head, one in the foot and the other on the posterior of the *two* adductor muscles, which are used to hold the shells shut. In the foot are developed auditory vesicles—ears.

The sexes are distinct. The ova of the female are conveyed, when mature, to her gills and there lodged. The male spermatozoa, which are minute, rod-like bodies, are thrown off into the water and may chance to fall into a current that will bring them to the feminine gills, where they meet and impregnate the ova, which are spherical with a tubular opening at one end. When hatched, the embryo has a bivalve triangular shell, a hinge along one side, and the opposite points open and curved in toward each other. When these young *Glochidia*, as they

* Huxley's Biology.

were once called, are turned out for themselves, they dig their points of shells into something—often the tail of a fish—and pinch on. Then the gills are developed, the foot grows and the auditory vesicles are developed in it, the young *Anodonta* drops off into the mud and sets up for himself. Here is a tolerably high development. It is the highest in the Lamellibranchiate class. The oyster is much lower. He has a shorter head, that is, there is less of him in front of the hinge and more back of it. He has but one adductor muscle instead of two, and no foot, or almost none, no respiratory siphons.

Dana reports the shell of a *conocardium* found in the topmost layer of the Calciferous division of the Potsdam. This belongs to the upper or *siphon* division of the Lamellibranchs, but in the salt water section of the same, and though of high organization, it is not the highest. There is a considerable expansion in the numbers of species and individuals of the Lamellibranchs in the later epochs of the Silurian age.

There also appeared in the Lower Silurian, an Echinoderm—the Cystidean. This is the lower of two tribes of Crinoids, the other being the Crinidea or Encrinites. They consisted of a stem with a bulbous head, from the center of the top of which, in some cases, two or more arms proceeded. This animal had a great run, taking on a great diversity of details in form, and expiring in the early part of the Devonian age. It is the forerunning type of the Crinids and Pentremites, and is probably an antecedent relative of the star fishes, some of which occur in the upper part of the Lower Silurian.

There is also the little animal in a bivalve shell, called the Ostracoid, from its resemblance to the oysters, but it is a crustacean in reality. It was generally very minute in size—from one-fortieth to one-thirtieth of an inch in diameter, but occasionally became as much as one-fourth of an inch. It very closely resembles in structure the *young* of the tribe which includes the cirripeds (Barnacles and Anatifas), which did not appear till long after. There are genera of ostracoids still extant, but probably not much like those of the Potsdam. But the most remarkable animal of the age was the Crustacean Trilobite. He appears to consist essentially of a worm composed of segments or somites arranged one behind the other, as in the articulate worms, and diminishing in diameter from front to rear. On each side, each of these segments is extended, terminating in an edge or point. The effect is to produce a *lobe* on each side of the worm-like central part. The limbs, if there were any, were attached to the underside of the segments. The front or head segment was widened like the rest, and covered with a crust, and contained eyes, stationary and compound, like the articulate eye of the present day. In general, each segment was covered with a strip of the shell or crust, terminating in a point turned down at each flank of

the animal. In length, they varied from a few inches to two feet. There were, first and last, nearly 1,600 species of them. They became extinct in the beginning of the Carboniferous age. They belong to the lower division of the crustaceans, viz., the *Entomostracans.* They are very like the larvæ of the King crabs and other crustaceans, and are, very probably, also the antecedent relatives of the Eurypterus, an advanced entomostracan, which came in during the last period of the Silurian age.

The life of the upper part of the *Lower* Silurian, requires no special mention.

The shales of the Hudson period contain a great amount of carbonaceous material, which was quite certainly derived originally from the plants, although the animal remains, doubtless, directly contributed to them. This is evidence of the growing amount of organic matter on the earth—both animal and vegetable. The rocks, too, attest many variations in minor details of animal development. Species and genera are constantly becoming extinct, and new ones are being introduced, yet the general types remain more or less constant. The new species are, as a rule, more complicated in structure—the shells of more intricate pattern—than their predecessors. Among the new Gasteropods, that came at that time and have staid to the present time, is the Limpet or Patella family. Two other families, the Haliotidæ, embracing the Pleutomaria and Murchisonia, and the Atlantidæ family, including the Bellerophon and Cyrtolites, came in at this time also, but became extinct in the Carboniferous era. "A whole family, in the case of the Graptolites, approaches its extinction." "Nearly all the genera of the Cystideans also became extinct." This singular type of Crinoids had its climax in the Lower Silurian, though not its final extinction; after this its species were few, while there is a great increase of Crinideans.*

Upper Silurian.

Now passing into the upper silurian we have a continuation of the same story.

A crustacean, which might be taken for a cross between a worm and a cray-fish, made its appearance about the close of the Upper Silurian. It is called Eurypterus remipes.

"The range of animal life was, in its grander divisions, the same as in the later part of the Lower Silurian." Nevertheless, great changes are constantly going on through the disappearance of many species, genera and even families, and the introduction of others. The details of family life are entirely remodeled, while the general structures remain. "Not a species existed in the latter half of the Upper Silurian that was alive in the latter half of the Lower Silurian. Less than a dozen species

* Dana 225.

are continued into the Devonian, and these disappear long before the close of that age." The number of *species* thus extinguished from the latter half of the Lower Silurian to the Devonian, is estimated at 880.† These are *species*, not families or orders. This general extermination extends, however, by the close of the Upper Silurian era to many of the *genera* as well as their species. Moreover, "To the list of existing genera no additions are made in the course of the Upper Silurian. All but the few before enumerated, viz., ‖ *Lingula*, ‖ *Discina*, § *Nautilus*, ‖ *Rhynconella*, ‡ *Pleurotomaria*, and ‖ *Crania*, become extinct."

This is American history; but the European is much like it. Many genera are common to both continents. "Similar genera make their appearance and others their exit. In neither have we any evidence that the progress had reached to the introduction of land or fresh water species of animals, and no relic of a land plant has yet been discovered in the Silurian strata of Europe or Britain, except in the uppermost beds." The number of European species was also large in the Upper Silurian, reaching over 2,000 in Bohemia. The Upper Silurian "was an era of small areas of dry land, of continents mostly submerged, though not necessarily at great depths, of warm waters to the poles, of marine life, of Mollusks and inferior Crustaceans as the higher life of the seas, and the flower-like Corals and Crinoids as the inferior life, and of Seaweeds as the vegetation." (Dana 265.)

Table of whole number of Silurian species, according to Barrande, up to 1872.

Sponges, and other Protozoans	153
Corals	718
Echinoderms	588
Worms	185
Trilobites	1,579
Other Crustaceans	348
Bryozoans (polyzoa)	478
Brachiopods	1,567
Lamellibranchs	1,086
Heteropods / Pteropods	390
Gasteropods	1,306
Cephalopods	1,622
Fishes	40
Uncertain	14
Total	10,074

All the species of the Silurian age are now extinct, probably half of them became extinct during the Silurian age itself.

Classification of Plants.

I.—*Cryptogams* (have no seeds—only spores).

1. *Thallogens*—wholly cellular,—(1) Algæ, (2) Lichens.
2. *Anogens*—wholly cellular, short stems, (Musci) Mosses, Liverworts.
3. *Acrogens*—(1) Ferns, (2) Lycopodia or Ground Pine, (3) Equiseta—horse-tails, scouring rushes (many coal genera).

II.—*Phænogams* (distinct flowers and seed).

1. *Gymnosperms*—flowers very simple, and the seed naked, the seed being ordinarily on the inner surface of the scales of cones. Exogenous—rings of growth, Pine, Spruce, Hemlock, &c. Includes (1) Conifers, (2) (Cycads), (3) Sigillarids—woody fibre without ducts.
2. *Angiosperms—Dicotyledons*—seed of two lobes.—Regular flowers and covered seed, Exogenous—bark and rings, Maple, Elm, Apple, Rose, and shrubs and trees generally.
3. *Endogens—Monocotyledons*—seed not divided—flowers and seed growing inside, no annual rings—no bark, new fibres formed among the old ones—Palms, Rattan, Reed, Corn Grasses, Lily.

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† This estimate is now known to be much too low. ‡ A Gasteropod. § A Cephalopod. ‖ Brachiopod families.

CHAPTER X.

DEVONIAN—AGE OF FISHES.

In this age we come to new general forms of life. The lower Period is called the Oriskany. The strata are sandstone, in some places several hundred feet thick. Their organic remains are in great profusion, but all are of the families represented back in the Silurian, Brachiopods, Gasteropods, Trilobites, Orthocerata, Crinoids and Cystids, &c. Old forms but new genera and species. The next Epoch is the Cauda Galli. This is so called from the abundant remains of a peculiar sea-weed of the Fucoid Algæ family, shaped like the tail of a rooster.

There are also beds composed of Protophite Algæ—Desmids and Diatoms. They are very abundant, but very minute, running from one-five-hundredth down to one-five-thousandth of an inch in diameter.

In the Upper Helderberg period, we find a new Brachiopod family, the Productus, which expires in the Permian period. There are also new species of Trilobites and Mollusks. But the most interesting are the Vertebrate remains.

These consist of the remains of fishes belonging to two of the three general orders of fishes, viz., the Ganoids and the Selachii or Placoids. They are found in the Schoharie grit about the middle of the Corniferous period of New York, and the corresponding strata in Ohio, Indiana and elsewhere. The remains are very abundant and some of the specimens are very large—as much as fifteen to twenty feet in length.

On top of the Corniferous strata come the Hamilton, 1,200 feet thick, and the Chemung, 1,400 feet thick. The first insects yet found are in New Brunswick, in strata corresponding to Hamilton or Chemung of New York. They are Neuropters—insects "having four similar membranous reticulated wings, as the species of Dragon-fly or Libellula, Termes, Phryganea, Ephemera." Those of the Devonian seem to be Ephemera. Their presence is evidence of the existence of dry land and land vegetation.

In the Hamilton beds are the first undoubted specimens of land plants in America. They consisted of Sigillaria and Lepidodendron, both supposed to be related to the Ground Pine family. This period also produced a large new Cephalopod—the Goniatites; an advance genus of the Ammonites, a family that had a very large representation in Mesozoic times. But there were no vertebrates in the Hamilton, nor were there any in the Chemung period, although marine life was there as well represented as anywhere below. There was a great difference in the

species between the Chemung and the Hamilton. Land plants multiply, and the marine shell-fish show progress in forms.

The Catskill period, the top of the Devonian, shows more remains of Selachian and Ganoid fishes. This period lasted long enough to lay down strata to a depth of about 6,000 feet. The rocks of this period have but few animal remains, and their species differ greatly from those of the earlier periods. The plants are of the same character as those of the Chemung. It thus appears that the fishes occur only in the middle and top formations of the great Devonian age in America, and that there was an enormous duration of its time before any fish came to America; that afterward they left, and another vast period clapsed before any more came.

In the European Devonian, or "Old Red Sandstone," as the British call it, the case is similar. In Scotland, the age is divided into seven sub-divisions. The second from the bottom contains the *Dipterus*, *Pterichthys*, *Cocosteus*, &c.; the fourth contains the *Cephalaspis*, &c., and the top, the seventh, contains the *Holoptychius*, &c. All those named here belong to sub-divisions of the Ganoid fishes. This tribe is now represented by the Polypterus, the Lepidosteus or Gar-fish, the Amia and the Sturgeon. The Ganoids have a cartilaginous skeleton, instead of a bony one as the *Teleostei* have. Their skull and lower jaw are somewhat bony, and there is a clavicle in the pectoral arch. The heart has two lobes, an auricle and a ventricle. The spine extends to the end of one branch of the tail, which is heterocereal or unequally divided.

These fishes are, on the whole, inferior to the *Teliosts* or bony fishes, which order comprises all the common fishes, such as the Eel, Herring, Pike, Carp, Salmon, Trout, Cod, Perch, Mackerel, and many others.

The skeleton of the Teliost is well ossified, including skull, jaw, clavicle, &c. His spine ends at the root of the tail fin, which is equally divided or not divided at all. His optic nerves *decussate* or cross each other. That he is later in time than the Ganoid, is proved by embryology, since the embryo of the Teliost is the equivalent of the adult Ganoid (See fig. 55). The Teliost does not occur in the Geological strata till the Cretaceous times—many long ages after the Devonian. The Selachian or Placoid is inferior in many respects to either the Teliost or the Ganoid. His skeleton is generally wholly cartilaginous. His skull is a cartilaginous box without sutures. He has no clavicle, or collar bone. His gills are not covered by a lid or operculum as in other fishes. His mouth is on the under side of his head. His heart is two-lobed. To this order belong the Rays and Sharks. It is to some subdivisions of these two orders, Placoid or Selachian and Ganoid, that the remains, found in the Devonian strata, belong. The Placoids are all of three orders of the Shark tribes. While it is quite certain that the os-

seous fishes are derived from an ancestor that was also ancestor to the Ganoid, and more remotely from an ancestor that was ancestor to the Selachian, yet it is very evident that after the separation of these families from the Teliosts, both of them took on characteristics that afterwards appeared in the Reptiles. It would indicate that the original stock also contained the reptile element, and that the Reptile is a branch taken off the main stem, close to its junction with the Placoid. The features alluded to are these: The eggs of some of the Sharks of the present time are impregnated in the ovary of the mother. They are few in number, large and well covered, like those of some reptiles and birds. Other Sharks hatch the eggs and bring forth the young alive, as some reptiles do. "In some cases there is even an attachment between the yolk sac of the internally hatched young and the oviduct of the mother, somewhat similar to that of the placenta to the uterus of the mammal. The young of Placoids, also, at first have a kind of external branchiæ (gills) like those of amphibian reptiles." (LeConte's Geology 331.) The Ganoids, on the other hand, possess the armor teeth, swim-bladder, paired fins and tail fin of the lower reptiles.

CHAPTER XI.

CARBONIFEROUS—COAL AGE.

This age is distinguished by the luxuriance of its vegetation, which it laid down in vast strata in many places, and the consolidation of which, under pressure, gives us our coal. The age is classed as Paleozoic, by the geologists, because its features, of both animal and vegetable life, remain, in general, the same as of old, and distinguish this and preceding ages from those which follow.

By this time a considerable portion of the earth's crust had become raised above the water, and land plants had an opportunity to flourish. The vegetation became rank and large compared with that of the same families of the present time in the same latitudes. There is a continuation of the sea-weeds. The land plants represented were chiefly Acrogens—Ferns, Lycopodia or Ground Pines, Equiseta and Calamites. These are of a low order Botanically, but they made up in size what they lacked in organization. The ferns we see now are only three or four feet high. But then they sometimes grew in the United States as they do now in the tropics, a bunch of leaves on the top of a tree stock many feet high. The Lycopodia were then sixty to eighty feet high, now they are mere shrubs. The common scouring rush is a modern Equisetum, but in the Carboniferous age the Calamite, which has been classed by some as an Equisetum, was thirty feet high and two feet in

diameter. It has been doubted if it belongs with the Equiseta, which, in the tropics, now grow thirty feet high but very slender. The ancient calamite had whorls of scale-like or thread-like leaves at the joints, which, however, the Equiseta have also. Yet from their size and their appearance of having exogenous woody tissue, LeConte proposes to class them as a cross or connecting link between the Equiseta and Conifers.

The Lepidodendron (scale tree) grew to the height of forty to sixty feet, with wide spreading roots. The surface of the trunk and branches was scarred or marked all over in rhomboidal patterns and covered with scale-like or spine-like or needle-like leaves, the branches terminating in a club-shaped extremity, like the club mosses. And like the club mosses, too, they propagated by double spores—the microspore and the macrospore—answering to stamens and pistils. They are classed as Lycopods, with some characteristics of Conifers.

The Sigillaria was sometimes sixty to one hundred feet tall, gradually tapering, and fluted vertically, like a Corinthian column. It had wide spreading roots for the soft ground where it grew. In the flutings were series of seal-like impressions on the bark. These trees are related to the Lepidodendrids on the one side, and have also characteristics of the Cycads, which made their appearance in the Triassic.

In addition to these there are logs, stumps, fruit and leaves of trees that are classed as belonging to Conifers. Some of them resemble tropical Conifers of the present time. "Their nearest living congeners seem to be among the tropical family Araucariæ (Norfolk Island pine), or among the broad-leaved Conifers, like the Salisburia of China and the curious Welwitschia of South Africa. This last anomalous Conifer, with a trunk three or four feet in diameter and only one foot high, bears but two strap-shaped leaves, (the original cotyledons) of great size (two or three feet wide and six feet long), which last during its whole life of 100 years."* Other forms are equally odd. These descriptions are of representative forms. The whole number of species is over a thousand in America and Europe, of which about one hundred and fifty are common to both continents. In this list there are no Angiosperms, such as the maple, elm, apple, &c., and no Endogens—grasses, cereals, reeds, palms, &c. The appearance of these more highly organized plants occurs much later, viz., in the Cretaceous period. *A few mushrooms appear.*

As to animal life there is the same general changing of genera and species among the mollusks, corals and crinoids. But there are some quite important innovations. Dry land led to new possibilities, and we now have forms impossible before. Among the Articulates (Arthro-

* Le Conte 347.

poda) there are *centipedes*, also *insects* of the cockroach family. An air-breathing Gasteropod (Pupa, the land Snail), the Cyclas, a fresh water bivalve, and the *Cypris*, a little Ostracoid Crustacean bivalve, make their appearance.

The Marine Vertebrates are of the same families of Selachians and Ganoids, with many new and advancing forms, but there is an animal, supposed to be a swimming lizzard, apparently foreshadowing the Ichthyosaurus of the coming Jurassic period. Other remains are of Batrachians and of a Salamandroid land animal or Amphibian, supposed to be two and a half feet long. "The body was covered with scales, and the whole surface of the cranium was sculptured. Dawson regards it, therefore, as most nearly related to the Labyrinthodont."*

The amphibians are a type in advance of the fishes, and appear to connect them on the one side, with the mammals, reptiles and birds on the other. The Urodela, or tailed amphibians, represented by the Newt (*Triton*), Salamander, Mud-eel (*Siren*), Axolotl (*Siredon*), and Giant Salamanders, are more or less fish-like. They all have gills to begin with, and some retain them through life, others retain the gill openings but lose the gills, while still others lose both and breathe through lungs. The *Anoura*, or "tailless," include the frogs, toads, &c. They are an advance on the tailed amphibians, and are, undoubtedly, derived from them. In an extinct group of the tailed amphibians, there are scales, which would indicate their fishy relationship.

The embryo frog, while still within the egg, assumes the form of a minute fish, devoid of limbs and with only rudiments of gills. After it is hatched it gets three pairs of external gills, then these are covered up, and internal gills grow from them. Then the lungs are developed, and, for a time, the tadpole breathes through both lungs and gills. The heart, at first, has two chambers. When mature the frog is devoid of tail. His heart becomes three lobed, consisting of one ventricle and two auricles. His lungs are in two lobes, right and left. He has kidneys, pancreas, spleen and liver, and a bilobed urinary bladder. He has a brain with cerebral hemispheres, olfactory lobes and olfactory nerves. He has a tympanic membrane, behind which is a tympanic cavity connecting with the mouth by means of eustachian recess and posterior nostril. But there is no external ear shell. Skull is partly bony and partly cartilaginous. The tibia and fibula bones are fused together, coracoid bone joins sternum and clavicle. He has a premaxillary jaw bone. The *duodenum* forms a loop with the stomach. The digestive, urinary and generative organs all discharge into a common cloaca, which has one external opening. He is therefore monotrematous, like the bird and ornithorhynchus. The fore limbs have four

* An Amphibian. Dana 351.

fingers besides a rudimentary thumb concealed under the skin. The hind limbs have five digits.

The Amphibian performs in his own person the passage of his ancestors, from the fish type to the reptilian type.

The Labyrinthodont, mentioned above, constitutes an extinct order of Amphibians that ranged from the Carboniferous into the Trias. It was a frog with salamandriform body, weak limbs and long tail. Its size was three feet long and two feet wide. On each of its limbs there was a hand with four fingers and a thumb. It was partly covered with bony scales over the body, and there were bony plates over the head. It had strong jaws and conical teeth like those of the Ganoid fishes. A cross-section of one of these teeth shows a remarkably complicated folding and plaiting of the dentine and enamel composing the tooth. The same thing is observable in the tooth of the ganoid fish, except that the convolutions are simple and comparatively plain. A great many species of these animals have been found—thirty-four species of seventeen genera, in Ohio—representing characteristics connecting them with the ganoid fishes and with snakes, lizzards, and other reptiles.

The coal producing era in America, was brought to an end—not suddenly, however—by the wrinkling up of the Appalachian ranges of mountains.

CHAPTER XII.

MESOZOIC—REPTILIAN AGE.

The Mesozoic or Reptilian Age is divided into three periods in Europe—Triassic, Jurassic and Cretaceous. The names are retained in America, but the first two are not very definitely separated.

We still have in the Triassic advancing forms of conifers, also ferns, and a new form of gymnosperm, the *cycad*, which had its forerunner in Carboniferous times in the sigillaria. The Calamite and Lepidodendron have disappeared.

The Cycas was then sometimes thirty feet high. It still grows to that size in the tropics. Another genus of cycads is the Zamia, which occurs fossil and which still exists. It was very short, not more than three or four feet high and two or three feet in diameter. The cycad family is the predominant plant during the Triassic and Jurassic periods. *No Grasses nor Mosses.*

Animal life shows change and progress. The Echinoderm Cystids are gone, but there is a greater abundance of the Crinids, including the beautiful lilly Encrinites. As to the Cephalopods, the Orthoceras and

Goniatites are gone, and the Ammonites and Ceratites succeed them. The long race of the Trilobites is ended, and the Eurypterids, the forerunners of the Crayfish, are gone too, to be superseded by species of Macrouran (*long-tailed*) forms, more like the lobster and schrimp of the present. There are not yet any teliost fishes, but the ganoid type changes in that direction, and the tails are less heterocercal and in some cases quite homocercal, or equally divided, the spine ending at the tail fin. The Ceratodus, Australian mudfish, is supposed to commence here. See Fig. 61. Amphibians are strongly represented in the Labyrinthodonts and other forms. There are also animals of the Lizzard type approaching true reptiles, and others that appear to walk chiefly on their *hind* feet. There was one, the Otozoum Moodii, that thus walked on his hind feet, occasionally putting down the fore ones. The hind feet were twenty inches long and the fore feet about ten. They had four toes each (and probably a rudimentary thumb). Others had but three toes behind and four in front. The tracks made tend to become those of the toes (or fingers) instead of the whole hand as with the first of the Amphibians. Many three-toed tracks of this period formerly ascribed to birds are now generally admitted to belong to these quasi-amphibians—taking on bird characteristics. The beaked Saurians, also called *Anomodonts* (lawless-toothed), are peculiar to this period. The most extraordinary of this remarkable group is the *Dicynodon* (two-canine-toothed). This was a saurian with the head and nipping horny beak of a tortoise and with two long, curved, overhanging canine teeth from the upper jaw. Several species have been found, in one of which (the tigriceps) the head was 20 inches long and 18 inches wide. They have been found only in the *fresh water* Triassic of South Africa (Karoo beds). Several other genera of the same order (Anomodonts) have been found in the same locality. The Oudenodon had a nipping horny beak without teeth of any kind. According to Prof. Owen, this remarkable order combined the characters of crocodiles, tortoises and lizzards.

There has also been found what is supposed to be a part of a Pterodactyl, a singular compound which becomes familiar in the Jurassic period. In the upper part of the Triassic is found the first Mammal, only one or two specimens consisting of the jaw bones. They are classified as Marsupials related to the non-placental Banded ant-eater family *Myrmecobius.* *

The Marsupials of the present day are all found in Australia and the neighboring islands, except the Opossum group in North and South America. The opossum is as large as a cat and has a long, round, partly naked prehensile tail. The Myrmecobius has a bushy tail and

* Prof. Blainville and Dr. Grant hold that these jaw bones belong to an extinct reptile of higher organization than any now living, and are therefore not mammals. But the current opinion seems to be the other way. *See Cuvier, page 90.*

somewhat resembles a squirrel in size and appearance. The Kangaroo is the largest of the order and is sometimes six feet high. Some of the order are carnivorous, some herbiverous (as the Kangaroo), and others are omniverous.

The Marsupial brain is devoid of a corpus callosum and the hemispheres of the cerebrum are relatively very small. As in Birds and Reptiles, the venous blood is returned to the heart by two principal veins. As in the Batrachians, the pieces of the skull are not united by permanent sutures. The female in some genera has a double uterus, or rather two small uteri, each of which is simply an enlargement of the oviduct and communicates separately with the vagina. See fig. 80. Correspondingly, the male organ, in all except the Kangaroo and Protoros, is bifurcated or two pronged, and it has a backward direction, the scrotum being in front of it. The females of all the genera have mammary glands with nipples, and a more or less complete pouch formed by a fold of skin, which encloses the nipples. There is also a bone on each side projecting forward from the pelvis, which serves to protect the intestines from pressure when the young are in the pouch. These are the marsupial bones and are found in the male as well as the female, although the male has no pouch. The young are born in a very immature condition, and fasten themselves upon the teats in the pouch, where they remain fixed till able to care for themselves. The young of the Opossum are born after a period of 26 days uterine gestation. They are sometimes 16 in number, blind and nearly shapeless and weigh only a grain each.* They stick to the nipple for about 50 days, when their eyes are completed, and they are as large as a mouse and in the condition of new born mammalian infants. They continue to inhabit the pouch till as large as rats. The young Kangaroo when discharged from the uterus is only about an inch long.

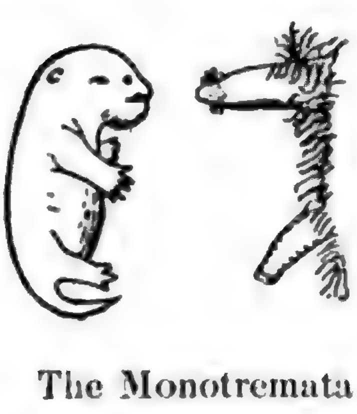

FIG. 72.—*New born Kangaroo (and teats of mother).* About equal to a human embryo of seven weeks. Compare with Fig. 32.

The Marsupials are called ovoviviparous and non-placental, because they discharge the live fœtus from the egg, and do not attach it to the uterus by means of the placenta, as the higher mammals do.

The Monotremata are so called because, like the birds, they possess but a single orifice for the discharge of excrementitious and reproductive matters. There are two genera and they are found only in Australia, viz., the Echidna, which has a long slender snout and feeds on ants, and the Ornithorhyncus, or Platypus.

*Cuvier, page 90.

They are further related to the birds in having an additional clavicle, something like the furcula or forked wish-bone of the birds, and also webbed feet; beside which the males have a spur on each hind leg, and the muzzle of the Ornithorhyncus is flat and projecting like the bill of the duck. Nevertheless they are mammals possessing milk glands without nipples, the young drawing their nourishment through pores or ducts in the skin. The Monotremes have the pouch bones, or marsupial bones, but they have no pouch. The young are probably left in their burrows instead of being carried about. They have no external ear. The Echidna has no teeth but some horny spines instead. The Platypus has in each jaw four back teeth, set in the flesh without roots.

The animal is covered with fur and is aquatic in its habits.

The *Jurassic* Period rather emphasizes what has been said of the Triassic.

The Cycad and its conifer congeners formed the heaviest part of the vegetation. Le Conte says this might be called the Age of Gymnosperms,* as the Carboniferous Age is called that of Acrogens. As to animals, the Ammonite family becomes very abundant. They vary in diameter from half an inch to three feet. The *genus Ammonite* musters about 500 species during the Mesozoic Age. Large Belemnites, the ancestors of the squid, are found. They flourish during this and the Cretaceous period and then become extinct. The Placoidean family, the sharks, now take on their modern teeth and become *Squalodont*, or *shark-toothed* (*Squalus*, a shark).

The Jurassic is remarkable for its development of odd and anomalous reptile forms, some of them huge and terrible. These are divided into three sections, the marine Saurians (Enaliosaurs), the land Saurians (Dinosaurs) and the flying Saurians (Pterosaurs).

In the first section is the Ichthyosaurus (fish Saurian). He was something like an alligator in appearance—from 10 to 40 feet long, 4 paddles something like those of a whale, head large, mouth long, set with sharp, conical, striated teeth, sometimes 200 in number, tail long and expanded vertically into a fin, eyes immense—12 to 15 inches in diameter. The vertebral joints were bi-concave like the fishes, instead of having the ball and socket attachment as with the living reptiles. He was carnivorous. Over 30 species of this chap have been found. The Plesiosaurus was another. His neck was long and tail short. His paddles were long. His total length was from 25 to 30 feet.

Pliosaur was another marine Saurian 30 to 40 feet long, something like the other, but more on the lizzard order. The land section Dinosaur contained the Megalosaurus, a carnivorous Saurian 30 feet long.

* This word means having *naked seeds;* and they comprise the Pine, Hemlock, Spruce, Cypress, Yew, Juniper, Arbor Vitæ, &c.

"Unlike all other reptiles the Sacrum corresponded to five combined vertebræ as in the higher mammals."* The haunch bone was prolonged backward as in birds, the hind legs were much more developed than the fore legs, and possessed only three fully developed toes, and the limb bones were hollow—like the bird's. "It seems certain that all the Dinosaurs *walked* with free steps like quadrupeds instead of *crawling* like reptiles, and some, if not all of them, had the power of standing and *walking* on *their hind legs alone like birds.* The backward elongation of the ischiatic bones seems evidently connected with the erection of the body on the hind legs."† The Iguanodon was an herbiverous Dinosaur some 30 feet long—with habits like a river horse. The Ceteosaur was also herbiverous—10 feet high when standing, and 60 feet long. His thigh bone was 64 inches long and 9 thick. This is the largest land animal ever discovered. There was another, very like a bird with long tail, long hind legs upon which he habitually walked, long neck and small head, with carniverous teeth. It is called the Compsognathus.

The Pterosaurs were represented chiefly by the Pterodactyl. This animal had a short body, and short spinal prolongation, large head with sharp conical teeth in a long Saurian mouth. His hind limbs were small, the fore limbs long and stout, with 5 digits on each. The outer digit was immensely prolonged to sustain the large membranous wing, as with the bat, leaving the other four free for grasping and clawing. The bones were hollow. In size they run in different species from 2 to 20 feet from tip to tip of wings. They became extinct in the Cretaceous period.

Besides these bird-like Saurians the Jurassic period furnished the first fossil bird with *feathers*—but a very Saurian-like bird. It had a long vertebrate tail containing twenty vertebræ, with a pair of long feathers for each vertebra, and jaws with reptilian teeth. The hand had four fingers all separate and two of them terminated with claws. This bird was found in the Jurassic of Solenhofen. Its whole length was 18 inches of which the tail was half. It was named the Archeopteryx Macrurus. Including the two or three specimens found in the Triassic, the number of mammals discovered previous to the Cretaceous amounts to about 20 species. They are all small marsupials and all insectiverous except one. The opossum and kangaroo tribes, pouched rats, etc., are the modern marsupials. (See tables.)

There is a considerable advance in insect life in the Jurassic and most of the general orders are represented as follows:

The *Neuropters* by the Dragon fly and Termes (white ant). The *Orthopters* (Locust family, etc.) by the Blatta Acheta, etc.; the *Coleopters* (Beetle tribes) by the Carabæus, Buprestis, Coccinella, etc.; the

* Dana 452. † Le Conte 431.

Hemipters by the Cicada; the *Lepidopters* (Butterfly, etc.) by the Tineites, Sphinx; the *Dipters* (House fly, etc.) by the Culex, Chironomus, Musca, etc.; the *Hymenopters* (Wasp tribes) by Apiaria.* The Crustaceans of the Jurassic make an advance toward the Brachyouran or (short tail) true crabs, by the broadening of the front end, the thorax, and shortening the abdominal region of the Macrouran or lobster forms.

THE CRETACEOUS PERIOD.

This period takes its name from the chalk beds of Europe. Chalk is pure carbonate of lime, and is shown to be composed of the shells of minute Protozoans, Rhizopods, Coccoliths, Coccospheres, etc., all which are carbonate of lime. Interspersed among these are the siliceous shells of the Protophyte Algæ, Desmids and Diatoms, which by a chemical process aggregate themselves into nodules of flint. Chalk is being thus formed in the deep sea now. Chalk covers about 800,000 square miles in middle Europe to a depth of 1,000 feet in places. But there is none in America. The time was occupied in America in the formation of other strata which geologists can identify.

The organic life of the Cretaceous shows important advances. In plants we have at least both Angiosperms and Endogens. The former include in Europe the Willow, Walnut, Maple and Holly, and in America most of the modern genera, Oak, Maple, Sassafras, Dogwood, Beech, Poplar, Laurel, Walnut, Scyamore, Hickory, &c. A few Palms have been found in Vancouver Island.

Some of the genera of the Cretaceous existed in greater variety of species than they do now. "For example, there are now only two species of Sassafras, one species of Plane tree, one of Liriodendron, and one of Liquid Amber. These are evidently the remnants of an extinct flora." (Le Conte 459.)

Besides the Protozoans named as being found in the Chalk, and as in fact furnishing the material for it, 100 species of sponges have been found. The Crinoids, which gradually supplanted the Cystids, almost run out in the Cretaceous. Thus Dana reports over 500 species as belonging to the Palæozoic, 75 to the Jurassic, and only 15 to the Cretaceous. The free Echinoids are abundant in the Cretaceous and many of them are similar to those yet found in the deep sea.

The bivalves (Lamellibranchs) are now in excess of the Brachiopods and of nearly all the modern types.

The Teliost fishes also come to the front. There are still plenty of the Ganoids and Placoids. But the Placoids (sharks) develop in the new squalodont characteristics—sharp, knife-like, smooth-margined, lancet-shaped teeth.

* Dana 461.

The Teliost fishes represented in the Cretaceous period include about 50 species, and belong to the Salmon, Herring and Perch families, &c.

The great Reptile tribes of the Jurassic are still represented in the Cretaceous, especially in America. "According to Cope, 147 species of reptiles have been described from the Cretaceous of North America."[1] Of these 50 are Mososaurs. "These reptiles are supposed to have been web-footed and aquatic in habit, while, at the same time, Carnivorous. The tail was flattened, long and powerful, and thus fitted for sculling through the water. The New Jersey species was 24 feet long."[2] Other species were more snakelike, and 60 or 70 feet long. They are related to the Monitor of the Nile. Forty-eight species belong to the turtle family. One found in New Jersey was almost 30 feet long and 15 wide. Its flattened ribs were not coalesced together to form the shell as in the *adult* turtles now. Eighteen species were Dinosaurs, and some of them were immense. One had thigh bones six feet long. The thigh bones of another were eight feet two inches long. "The animal itself, if its proportions were at all similar to those of a crocodile, must have been 115 feet long."[3] There were six species of Pterosaurs. These flying reptiles were toothless and their jaws were probably sheathed with horn, like the birds. One of them had toothless jaws four feet long and was 22 feet from tip to tip of wings.

Some of the European Jurassic reptiles are also found in the Cretaceous. In 1870 and 1871, Marsh discovered in New Jersey and Kansas five wading birds, five swimmers, and six species with *teeth*. The jaws of three of the species were long and slender, the teeth were sharp, conical and set in sockets, and numbered probably 40 in each jaw. These birds were about the size of a pigeon and were probably flying birds. The other three were five or six feet high but not flyers.

No Mammals have been found in the Cretaceous formations.

CHAPTER XIII.

TERTIARY—AGE OF MAMMALS.

The Tertiary Period is divided into the Eocene (the oldest), Miocene (the middle), and Pliocene (the latest). Epochs. Of plants nearly all the genera of Angiosperms (Dicotyledonous plants and common trees) and of Endogens (Monocotyledonous plants including grasses, cereals, Palm trees, &c.) were in existence that we now have, but the species were almost all different. The climate of Europe and America was vastly warmer than now. Sequoias, Magnolias, Cedars and Cypress

[1] Le Conte, 470. [2] Dana, 473. [3] Le Conte, 468.

flourished in Greenland and Northern Europe in the Miocene. There were local causes also favoring the growth of protophyte algæ—Diatoms—in certain places.

These minute plants have left their Siliceous shell remains in great beds. One in Bohemia is fourteen feet thick "and every inch of the material according to Ehrenberg contains 40,000,000,000 shells."[4] Another bed in Virginia is 30 feet thick and many miles in extent. Another deposit in California is 50 feet thick. These deposits were in part or wholly, fresh water deposits.

The animal genera of the Tertiary period are also chiefly those of the present, although species have greatly changed. Protozoa had a great representation. Nummulites, a Rhizopod family, built by the accumulation of their calcareous shells, limestone strata many thousand feet thick during the Eocene epoch in central and southern Europe, Asia and the central part of the United States.

Of insects all the orders were represented in the Miocene. In Switzerland 100 species of winged ants have been found—none appearing wingless. Le Conte judiciously observes that this must have been before the time when the female and neuter ants developed their present peculiarities, and both sexes remained winged alike during life. They were more numerous than now in Europe and were of tropical species.

"There are crabs and insects of nearly all the modern tribes excepting the higher group among the crabs, viz., the Maioid or Triangular."[5]

"Teleosts were first introduced in the Cretaceous, but only in the Tertiary did they become very abundant. Ganoids on the contrary became fewer in number and they sank into their present subordinate position.† Among the Placoids the Hybodonts are gone, the Cestracionts are few in number, but the Squalodonts reach their maximum development both in number and size."*

The great Saurians, Enalio-Saurs, Dino-Saurs, Moso-Saurs and Ptero-Saurs all became extinct in the Jurassic and Cretaceous. The representative reptiles of the Tertiary are crocodiles, turtles and snakes. There are some large Salamandroid Amphibians, one of which was four feet long. In none of these orders did the present characteristics prevail in the Tertiary, but they have been more or less differentiated and finished up since. (All the Tertiary *species* of *vertebrates*—including Fishes, Reptiles, Birds and Mammals are now extinct and we have other species in their places.)

The same sort of changes go on with reference to the birds. There were birds of strong reptilian characteristics and some wading birds in the Cretaceous era. In the Tertiary great improvements appear in

[4] Le Conte 484. [5] Dana 514. † The modern Ganoids are fresh water fish only.
*Le Conte 491.

these. The reptilian teeth and vertebrated tail disappear—and birds become birds instead of flying reptiles.

The Tertiary birds of the United States were such birds as we yet have, woodpeckers, eagles, owls, etc. But in Europe, the birds, like the plants, were in part tropical—parrots, trogons, adjutants, &c., besides cranes, swallows, pheasants, owls, vultures, &c. But the crowning fact of the Tertiary was the existence of the placental mammals. In the first epoch of the Tertiary they are found in large numbers in the western part of the United States. "Marsh finds 150 species of vertebrates of which the larger number are mammals, some herbivora, some carnivora and some Lemurine monkeys. The same species do not continue through the Tertiary. On the contrary the mammalian fauna changes completely several times in the course of that period."[6] The greater number of the mammals are herbivores, and the predominant type is that of the Tapir. But nearly all the types are of a general and connecting nature combining characteristics that are now specialized and and divided among several types. There are 40 species of *Tapir-like* animals in France in the Eocene—none of them Tapirs. The Palæotherium was a cross between the Tapir and the Horse of the present. It had three hoofed toes on each foot. The Tapir now has three on his hind feet and four on his front feet. The Paleothere had a long neck and high head and long legs, in which respects he more resembled the Horse than Tapir.

Another, the Anoplothere, had a long tail and two toes on each foot and was devoid of a snout. He is thought to be a connecting link between the Tapir and the Ruminants. In the American Eocene seventy or eighty species of mammals have been found (in the Green River Basin —fresh water deposits S. W. Colorado). The most of them are more or less Tapir-like. Another, the Dinoceras, was elephantine in size, had six horns, two tusks and probably a trunk or snout, and five toed feet. The Tillotherium combined characteristics of the bear and rodent with the general features of the Ungulates. The Oreodon of the Miocene of Nebraska combined features of the hog, the deer and the camel and ranged from Nebraska to Oregon. There are also many species related to the camel and horse.

There was a marked improvement between the Eocene and Miocene, the same species becoming larger, and the new orders and genera being of the greater and more bulky types. The Dinotherium of the Miocene of India, an immense brute, "combined in the structure of its head the characters of Elephant, Hippopotamus, Tapir and Dugong: but it also had affinities with Marsupials" for it possessed the *pouch bones.*[7] The Sivatherium from the same quarter, an enormous Antelope with four

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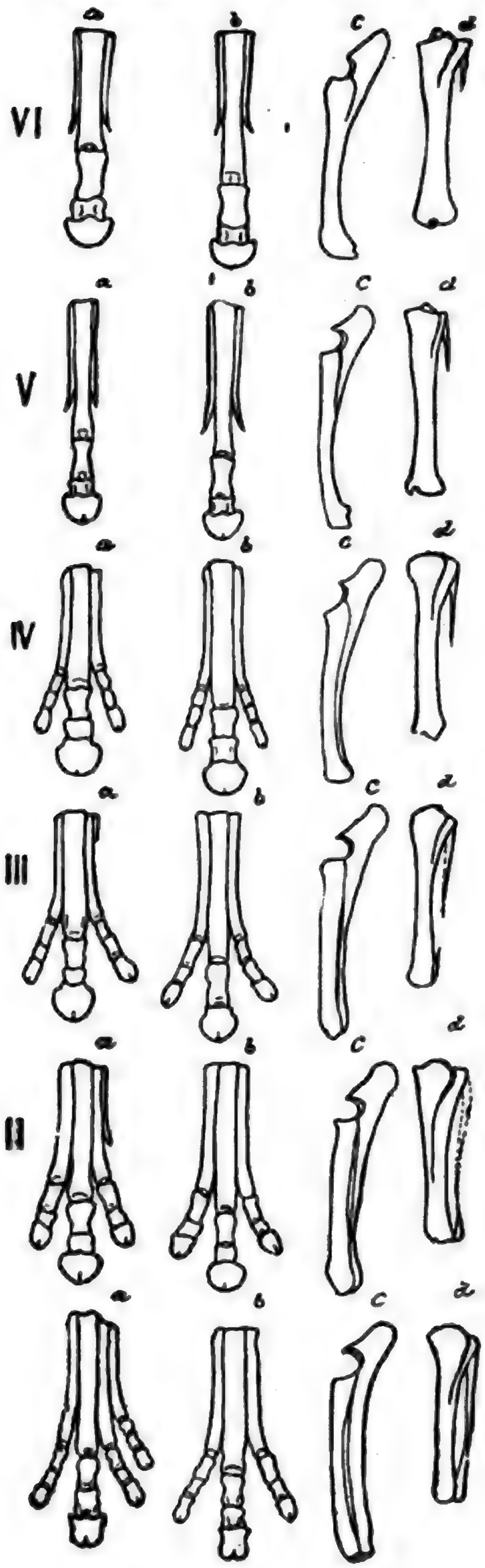
[6] Le Conte 495. [7] Le Conte 498.

FIG. 73.—*Twenty-four Figures of Horses' Left Feet, &c., Showing Development from the Eocene to the Quarternary and Recent Periods.*



I. Orohippus—Middle Eocene.
II. Mesohippus—Lower Miocene.
III Miohippus—Miocene.
IV. Protohippus—Lower Pliocene.
V. Pliohippus—Pliocene.
VI. Equus—Quarternary and Recent.
a—Fore foot.
b—Hind foot.
c—Fore arm, Radius and Ulna separated in the lowest but gradually fused together as we ascend.
d—Shank bone or tibia. The fibula which is fully formed in *Orohippus*, is gradually reduced to a mere splint as we ascend.

horns—two heavy palmate ones in the usual place and two short ones pointing straight out from the forehead—with the feet and legs of a ruminant and probably a snout, was a compromise between a ruminant and a pachyderm. There were many other such combinations too numerous to mention. The general advance and specialization of the times in regard to mammal life is shown in the brain development of some of these larger types, the later ones showing *cerebral* lobes of twice the bulk relatively to the *cerebellum*, that the corresponding earlier ones show.

Some remarkable facts in this direction constitute the history of the horse. There were 35 or 40 species of the horse in the United States ranging through Tertiary times. The development is in part a reverting one—as relates to the limbs at least, which are improved for the use of the animal by the addition of *minus* or subtractive values. It is quite certain that *five* is the typical or original normal number of mammal toes and fingers. For the sake of speed or lightness of step, or to

add to the height of the body, various tribes have taken to walking on their tip-toes; that is, have become digitigrade. In the case of the horse, he has, in addition, discontinued the use of one toe after another, thereby losing the use of them, till only one toe is left. The radius and ulna of the forearm were gradually coalesced into one bone in the course of development, and the fibula of the hind leg was by degrees aborted, the tibia acquiring greater size and doing the work of both. The most ancient horse in America is from the Eocene of the Green river basin in southwestern Colorado, and was named *Eohippus* by Marsh, who made the discovery. This horse was no bigger than a *fox*. The bones of the leg and forearm were entirely distinct, as in man. On the fore foot he had four serviceable toes and a rudimentary or partly aborted fifth one. On the hind feet were three toes. Another horse, same size, in the Middle Eocene, had quite dropped the rudimentary toe of the fore feet. In other respects he resembled the first. He is named *Orohippus*. In the Lower Miocene another horse much the same as the first, had dropped the use of the fourth toe, which was reduced to a rudimentary splint. That is the *Mesohippus*. The *Miohippus* is found in the Miocene also. He was about the size of a sheep. In him the ulna and radius are pretty well consolidated and the fibula reduced to a rudiment. He has three toes on each foot, beside a faint rudiment of the fourth on the fore feet. In the Lower Pliocene is found the *Protohippus* of America and its equivalent, the *Hipparion* of Europe. It was about as large as an ass. Three toes all around and no rudiment of the fourth left.

Higher in the Pliocene is another, the *Pliohippus*, who has but *one toe* on each foot, the other two appearing on either side as rudimentary splints. The consolidation of the two bones of the fore arm is nearly complete, and the rudiment of the fibula diminished.

The *Equus*, or *horse*, of the Quartenary and the present is an improvement on this animal in the shape of the head, size of the brain, proportions of the body and limbs, style of the teeth and various details, which together make a vast differenee in the functional value of the animal.[a] The Eohippus named here is certainly not the first of the horse family. He was undoubtedly an immigrant to this country. His ancestors in Asia, or wherever they began to diverge from the Carnivorous and Omnivorous tribes were five-toed.

The history of the Camel is similar to that of the horse. He came to this country in Miocene times, and during that and the Pliocene became modified into the modern camel form.

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[a] See Le Conte Geology, 510.

CHAPTER XIV.

QUARTERNARY OR POST-TERTIARY PERIOD.

This period is divided by American geologists into the (1) *Glacial* Epoch, during which the Northern parts of America and Europe were elevated one or two thousand feet, and the temperature so lowered as to produce an accumulation of ice from the pole to latitude 40° North in America, and to 50° in Europe.

(2) The *Champlain* Epoch, in which there was a gradual depression of the same regions until they were 500 to 1,000 feet lower than now, bringing large tracts under the sea.

(3) The *Terrace* Epoch, in which there was a series of slow elevations interrupted by occasional pauses—bringing geological history to the present or recent times.

The plants and marine shell animals of the Glacial Epoch are such as now live in an arctic climate. They flourished along the southern edge of the ice cap and emigrated North as that edge retreated at the closing of the epoch. The same progress in Mammal development that was noticed in the Tertiary period is continued into the Quartenary. The advance southward of the cold would drive most of the species south and modify all of them. On the return of a favorable climate, the living representatives of the old tribes came back, and new ones with them. All the species seem to be at their best, and the remains of Mastodons, Elephants, Bisons, Horses, Stags, Beavers, are all called "gigantic" of their kind. There were Tapirs, of course, and Peccaries and Edentates from South America. There were two species of Bear and one of the Lion. The climate during the Champlain Epoch, in which the greater part of Mississippi valley was down almost to the level of the sea and much of it submerged under the warm waters of the Gulf, was very favorable to the support of very populous tribes. But the gradual elevation of the continent during the Terrace times brought unfavorabe conditions. In addition to this, I suspect that one of the most unfavorable circumstances was the advent of MAN upon the scene soon after the close of the Glacial Epoch. It is pretty certain he came before the extinction of the great Mammals, an event to which he certainly contributed. There is evidence of his presence both in Europe and in this country, on the Pacific slope. Probably he came into the Mississippi valley later, and it is probable that the great Mammals were there to a comparatively late date.

The European Quarternary has a history quite like the American.

The remains of Man accompany those of the Elephant and Hippopotamus, and are contemporaneous with the Cave Bear, Hyena, &c. Similar associations have been found in South America in bone caverns and also in India. In all cases he appears as an emigrant with the other Mammals and already living at their expense.

The following is from a Newspaper: "Prof. E. D. Cope, of Philadelphia, has secured the skull of an extinct monkey which seems to fulfill in a remarkable degree the condition of the missing link between man and the lower animals. It is not larger than the skull of a small ground-squirrel, and belongs to a species of marmoset. It was found in the valley of the Big Horn river, Wyoming territory. The professor says: 'This skull is remarkably similar—in miniature, of course—to the human skull. The brain space is remarkably large, and is, in fact, several times larger than the brain space of any of the skeletons of animals of the same period of time. The characteristics of the formation of the human skull are clearly defined—so clearly as to be remarkable. The teeth are almost the same as human teeth, while the jaw has many strong points of similarity. I consider this skull as the earliest indication of the existence of man. It is a new species of a familiar class, and has hitherto been unknown to scientists. The connection between man and this animal, it seems to me, must have been very close, although, of course, nine men out of every ten would raise a dispute. No animal at that time, except this peculiar species, has a head like that of a human being, and the brain space, contrasted with the brain space of other animals, or even of the monkeys of to-day, shows a vast superiority of intelligence.'"

CHAPTER XV.

THE GEOLOGICAL LESSON.

From the foregoing hasty survey of the Geological history of organic life it is evident that there has been general progress in the types of life from the beginning to the end.

The Silurian age, the first that gives us positive information as to its organic life, was the age of Mollusks. These are lower than the Vertebrates. It was also the age of Algæ, the lowest of the plants. In the Devonian, Fishes, the first of the vertebrates, are the dominant type. In the Carboniferous, Acrogens are the best type of vegetation and Amphibians of animal life. The Mesozoic or Secondary is the age of Reptiles. It also saw the advance of vegetation from Acrogens to the higher classes. Angiosperms and Endogens. The Tertiary age estab-

lished the Mammal as the highest animal type and perfected the development of Endogens—grasses and cereals—necessary to sustain that high type.

Thus Geology shows in general an advance in life from age to age both in the animal and vegetable kingdoms. Yet there are many changes which are not advances. Genera, tribes and races by the thousand have gone down hill and have finally disappeared. But the flexibility of organisms has always permitted their environing influences to alter and adapt some of them to every new condition as it has arisen. The theory of evolution requires that organic life should begin with the simplest forms, and in the nature of things, no kind of differentiation can take place in the simple without producing the complex. But when a degree of complexity has been reached it does not follow that further differentiation will increase the complexity. It may diminish it. A son may be inferior to his father. This point has been alluded to before.

Personal development or individual growth part by part from the embryonic germ as we have seen, is by way of a series of steps or stages, each one of which is the equivalent of the permanent value of the same part in an ancestor. But this general truth is more literally and minutely true in the case of the lower types than in the higher. We have good reason to believe that in the embryonic development of the highest types many cut-offs or short cuts are taken, and steps are skipped, or two or three steps condensed into one. All along the Mississippi river there are bayous and lagoons. These are sections of river bed which the stream has abandoned. They are usually in the shape of a circuitous bend, across the isthmus of which the river has cut a new connection. And they remain there like atrophied rudiments. In the course of time they become filled up and obliterated, while new ones form elsewhere. This is something like the action in embryonic and race development. The rudiments which we see left behind after the embryo is complete are really but a small proportion of the whole number; the majority having been aborted and obliterated during the development. As in the course of race evolution these steps increase in number they are crowded together, till finally many of them become quasi simultaneous that were originally consecutive. And the growth proceeds across the isthmus and the bend is not constructed at all.

This modification of the track or path of development is the expression of new adaptations of organs and parts, which adaptations may be reversions or degradations instead of advances. Thus the legs of a mammal have been developed from the fins of fishes. The flippers of the whale have in turn been developed from the legs of the mammal. It would probably be less work to turn fins directly into flippers, than

first into legs and legs into flippers. So that the leg stage of the process would gradually be eliminated and more or less of a cut-off be made, and while it is an advantageous modification or adaptation, it is nevertheless a retrogression.

In applying evolution to the details of animal advance as we find it in geology, it is necessary to keep this consideration in view; because frequently the first species we happen to find of a new type or family is not the lowest or least developed of that family. Thus no Ornithorhynchus or Echidna has been found fossil, although they belong to the lowest order of the mammalia. But this animal may be descended from an ancestor common to himself and the Marsupials, and while he has become adapted to an inferior mode of life, the Marsupial has diverged in the other direction. They both have Marsupial bones which are probably the remains of a posterior sternum possessed by the common ancestor, and which have been turned to use in the kangaroo, &c., in supporting the marsupium or pouch.

In like manner the Edentates are first found in the Miocene, while both herbivores and carnivores, superior to them in organic structure, appeared in the epoch before. But the Edentates do have teeth at first which are good enameled mammal teeth; but they lose them and get others of an inferior development in their place. They are thus shown to be degenerated from the higher mammals and so *ought* to come later. There are no doubt many other such cases in which the later inferior species are descended from superior by retrogressive adaptation.

Again, Snakes do not appear till the Lower Tertiary, while their superiors, the Turtles and Lizzards, occur in the Triassic. But Snakes may be a later off-shoot of the Amphibian Salamanders, as the Saurians were an earlier, or they too may be degenerate amphibians. The Salamanders continued to be Salamanders after they diverged from the Reptiles and it is not improbable that when land appeared suitable for a new form of reptile, a family of Salamanders might become modified by it into the snake form.

Many of the Snake tribes have rudimentary limbs, which in some cases appear outside of the skin as small hooks, in other cases do not cut through the skin, and are only insignificant rudiments or vestiges. The lungs in most species are more or less aborted; that is, one of them is reduced while the other is full sized. These are marks of retrogressive adaptation and show the Snake to be a modified form of Amphibian reduced in respect to limbs and lungs. On the other hand, their reproductive apparatus and process are very superior to the Amphibian, since they reproduce by eggs internally impregnated, and in the case of the vipers, the eggs are internally hatched and the young born alive; while the Amphibian eggs are first laid and impregnated

afterward. In this respect the snakes show improvement since their separation.

Again, Dana remarks that the Trilobite, which was among the first Crustaceans, was superior to the Barnacle, which did not appear till the middle of the Reptilian Age. But the origin of the Barnacle was very probably by development from the Ostracoids, and a late off-shoot. The Ostracoids have run from the Silurian to the present time, under varying genera, and may have developed more than one articulate off-shoot.

Dana observes further that Mosses and Lichens appear after the Acrogens of the Carboniferous era.

This may be accounted for in more than one way. Both Mosses and Acrogens are derived originally from the great Algæ family. There are many different forms of Algæ, and one form may have been the ancestor of a Moss and another of the Acrogen. Placed under different influences their evolution might have advanced at very different rates, and the conditions necessary for one development have been retarded ages behind the other. A fungus like a mushroom is of the simplest form and the most limited function, yet it is of comparatively recent origin, because, having no powers of its own for the manufacture of food from the mineral kingdom, its life could begin only after better equipped organisms had existed and prepared food for it. See chapter on Fungi.

Another remarkable circumstance is that sometimes the first animals of a family or order that appear are too different from that family which went before to warrant the belief that the last could have been derived from the first by modification or development.

Thus the Trilobite appears in the Lower Silurian, with no remains of immediate relations to show his lineage and connections. He was undoubtedly originally from the worms, and possibly his immediate ancestors may have lived in the same seas, but like the other worms have been destitute of an organization that could be preserved. But I think it more probable that he was an immigrant where found in this country and Europe. Between the end of the Laurentian and the beginning of the Silurian time there was a vast lapse of time in which nothing in the way of rock building was done on these two continents. The rocks of the early Laurentian times were being slowly raised and tipped up during a period of some millions of years, then held out of water exposed to the erosion of the elements till they were robbed of a mile or two of their accumulations. They were then in part sunk again slowly into the sea, and the work of building the Potsdam formations on them was commenced as they went down. The time during which this movement was going on is entirely unrecorded in any strata that are accessible to

us. The Potsdam lies directly on the upturned edges of the Laurentian rocks, although the seam between the two probably represents 30,000,000 years as estimated in the table, or quite as likely ten times that figure. During this long period the Trilobite becomes differentiated from some of the worm tribes in some foreign sea, and emigrates to America and Europe during the deposition of the Silurian rocks, leaving behind him his immediate relations and the "connecting links" that would indicate his pedigree.

The same consideration applies to all the life of the Silurian times. It is not likely that any of the tribes originated on the spot. Life had begun on earth probably 100,000,000 of years before that time, and and only spread itself into the *west* as the conditions for it became possible. When the species become established, there is no difficulty in tracing much of the gradual modification of forms that the varying conditions of climate, &c., worked in them during the long comparatively peaceful ages of the Palæozoic times. In such cases the blood relationship of the modified forms to the old families on the ground is clear enough. But where a type differing materially from the old forms makes its appearance we may be sure it is an emigrant.

This is certainly true of the first fishes that appeared in America and Europe as mentioned above. They arrived in America and multiplied rapidly during the Corniferous period of the Lower Devonian age. But the changes in the next period were unfavorable to them and their colonies died out and it was probably half a million years before a permanent settlement was effected—during the Catskill period. This is like the history of human colonization too. Many of the first efforts to colonize America by civilized Europeans were failures.

All through geological history the tribes and families were going and coming. While they remained here we can trace the changes stamped on the species from period to period. While they were in foreign parts the modifications went on in their structure, habits, &c., all the same, but we have not in all cases found the detailed record. But when they return to our strata the sum of all the changes they have experienced through many generations of their foreign life is stamped on them and to the first geologists it seemed like a new creation.

Our first mammals both in America and Europe were little marsupials which appeared in the Triassic and continued to flourish through that and the Jurassic period. At the close of that period the lower rocks were tilted up and subjected during a long period to various oscillations and elevations and in some places denudation, after which they were again sunk beneath the sea and during 9,000,000 years more, from half a mile to 3¾ miles of Cretaceous rocks were piled on them. During all this time the mammal marsupial has disappeared from this part of the

world. But he was not exterminated from the earth, for the Opossum existed in Europe in Miocene times, and he exists at this day in the United States—besides many relative marsupials in other countries.

At the end of the Cretaceous period the table estimates a space of 15,000,000 years during which the European strata were repeatedly tilted up and pared off, and the mountain ranges in western North America were shoved up. The northern regions of both continents were subjected to repeated oscillations keeping them both pretty well elevated much of the time and at last leaving them above the sea as now.

In the Rocky Mountain region in western United States the Cretaceous beds are now from 4,500 to 7,000 feet above the ocean. This elevation has all taken place since the beds were formed under the sea and the most of it before the fresh water deposits of the Eocene could take place. So that although in America there is not the unconformability of strata that exists in Europe, yet the time which makes up the interregnum between the Mesozoic and Tertiary may have been equally long while more orderly. Yet it is not improbable that a part of the Cretaceous layers of America were put down during the disturbances in Europe and that the real halt between the periods of rock building was less here than there.

But during this long period from the end of the Jurassic to the beginning of the Eocene, which the table estimates at 24,000,000 years, in some primitive continent which might perhaps have occupied the site of the Indian ocean and South Pacific, with connection to Asia and South America and from North Asia to North America, mammal types had developed from the marsupials, and as the Asiatic, European and American continents became suited to their needs they spread themselves over them. America was probably invaded from the southwest or northwest, and Europe from the southeast. The species in the two continents in Tertiary times are nearly enough related to indicate a common origin, but not near enough to show that one was necessarily derived from the other. As shown above in the cases of the horse and camel, the first that came to America were already differentiated in an important manner from their original marsupial ancestors; a differentiation that certainly took place before the families diverged from each other in the primitive continent. After reaching America the modifications forced upon them here are easily visible—running through say 15,000,000 years as estimated by the table. It is indeed not impossible that during much of this time there was land all the way from western Europe eastwardly across Asia and the North Pacific to North America. But even if a single species were distributed across this whole belt, it would not be long before the varying conditions of climate and food along this belt would modify the various sections of the species into new

species. Although the horse in America was developed from a four and five-toed animal no bigger than a fox to a single-toed animal the size of an ass, it may be doubted whether this animal emigrated back to Asia, and if he did not, the horse must have had in Asia a development parallel to that in America. At any rate after the separation of the continents and the changes in climate during the Quarternary, the horse and camel became extinct in America but not in Asia. The same is true of the lion, the elephant, the lemurs, the tapirs.

Thus admitting that advanced life originated in some one spot, received its most rapid development and diversification there and spread thence to all other parts of the world, many of the phenomena admit of easy explanation. Some of the early geologists observing that the first representatives of a new type where first observed in Europe or America were frequently not the lowest members of that type but that they foreshadowed forms inferior to themselves as well as superior, gave these representatives the title of *Comprehensive types.* They appear to have imagined that they were introduced by supernatural power and placed on exhibition as it were; as a sort of sample average specimen of what was to be expected next. At the same time they are constantly showing how the oscillations of the land, the changes of continental outline causing variations of climate and vegetal productions, also affect animal life, causing changes of habit, action and food, and these reacting on the organism cause gradual changes in its physical structure. They show how it was impossible for land plants or animals to exist before land, and how the marine species became extinct when the sea bottom was elevated into dry land. Dana says there were 500 species of Trilo bites, 900 species of the Ammonite group, 450 of the Nautilus, and 700 of Ganoid fishes, and of all animals nearly 40,000 *species* have been gathered from the rocks.* In many cases these species graduate into each other in such a way that only an expert can separate them. Think of 900 *species* in one *family.* All the above are extinct—destroyed not by supernatural interference but by adverse natural conditions. As we can see the gradual development and general improvement of the species in the strata accessible to us, we have no reason to doubt that similar changes are recorded in the strata that have been sunk beneath the sea, or buried below the impenetrable deposits of other continents. Probably during nearly half the time that elapsed between the close of the Laurentian age and the beginning of the Tertiary our rocks were subjected to a process of denudation, and the materials torn off were piled away in the surrounding ocean. Such periods would be unfavorable for the preservation of land animals or vegetation *in situ,* and if any were preserved they are buried under the ocean, and marine remains would

* Dana 601. More species are now known.

be there too, of course. If these records could be reached it might appear that the larger mammals existed in America before the Eocene. At any rate we have no more reason to doubt that they existed on some other continent before the Eocene than we have to doubt that the marsupials were living somewhere else than America and Europe during the Cretaceous.

Le Conte suggests that there may be periods of extraordinary development; when changes in the environment of organic life are rapid enough to impose great and rapid differentiations on the organisms, but not so rapid as to kill them. No doubt there are such periods, but we must remember that the most rapid development is an exceedingly slow process. It is improbable that the mammals found in the Eocene of America could have been developed during that period from any animals here before that time. But the theory of emigration from a Primitive Continent gives all the time from the end of the Carboniferous to the beginning of the Tertiary for the development on that continent of the mammals from their oviparous ancestor by way of ovoviviparous monotremes and marsupials—a period estimated by the table at 55,000,000 years.

On the whole it appears that the geological record as we have it so far, is a largely mutilated volume. Alternate chapters have been torn out as it were, and while we easily catch the general drift of the history, details here and there have escaped us.

Another important consideration regarding geological history is still to be mentioned; and that is, that geological times of the same name in different parts of the world are not necessarily synchronous. The only way to identify strata laid down in remotely ancient times in different regions is by the identity or equivalence of their organic remains. If the theory that organic beings have peopled the different parts largely by successive waves of emigration from an original center, or a shifting succession of centers; it would naturally follow that the same families and genera would arrive at different localities in successive periods of time. There would be modifications in the character of the species during the migration, so that when installed in a new land some ages after leaving an ancient hive, the original family is represented by a new species, but because the family characteristics are retained, the age in the two cases is regarded geologically as the same.

CHAPTER XVI.

NATURAL SELECTION OF SPECIES.

Geological history shows and human observation during historical times agrees that there is a constant modification of the species of plants and animals. As one generation dies its heirs and successors are certain to differ in some respect from it, and the accumulations of differences repeated and added to each other finally amount to enough to justify the distinction of specific names.

It is not difficult to point out general causes that would tend to produce changes in organization, although it is not often possible of course to designate in detail the action of these causes in particular cases.

Animal life depends on plant life. Certain kinds of animals require herbage of a bulky and abundant kind. Our American Bison swarmed in great herds over the prairies of the west because among other things it had a vast abundance of nutritious grass. Wolves likewise were abundant there because the casualties among the Bisons furnished them with plenty of animal food. The grass in its turn depended on the quality of the soil and the amount of the rainfall.

The rainfall depends on the topography of the country. A different arrangement of mountain ranges and plains might have rendered the region rainless and barren like Sahara or Gobi, or subject to occasional protracted drouths fatal to herds depending on grass. The topography of the country in turn was determined by dynamical causes that were in action probably hundreds of millions of years ago, by which certain parts of the earth's crust became wrinkled into ridges and mountain chains and other parts elevated above the sea as plains. These dynamical forces in turn are traceable at last to the simple affections of elementary matter, of which gravitation is the first, if not the representative of all. Gravitation produced the motion of matter toward the common centers of systems, resulting in its accumulation in the form of globes, and in the evolution of heat, light and magnetism, if not chemical activity also. At any rate these causes, primary and secondary, have made the world as it is with seas, lakes, rivers, mountains, plateaus, low-lands and marshes, and established upon it every variety of temperature and many degrees of moisture.

Now without going into details it is plain that these general aspects of nature must possess an influence over the organisms within their reach. The diminution of heat on the approach of winter allows the polar cap of snow to spread itself 25 degrees towards the equator, and imposes upon the vegetable and animal kingdoms in these latitudes

enormous changes and preparations. The growth of vegetation in general ceases, and plants reduce themselves to the smallest compass by shedding their leaves, or even their stems and every part above ground. Some animals prepare themselves by constructing warm retreats, into which they convey stores of food, or in which they hibernate in a torpid and inactive state. All change their clothing whether it be natural or artificial, and vast multitudes migrate to more congenial latitudes. All this is caused by the fact that the axis of the earth is not perpendicular to the plane of its orbit. The plants and animals of the polar regions are very different from those of the equatorial regions, those of mountains and high plateaus differ from those of low plains and marshes, they of dry and barren countries are not in general like them of moist and productive regions, the inhabitants of the sea are not like those of the land. There is in all these cases obvious adaptation of the organism to its surroundings; the fish to the water, the quadruped to the land, the amphibian to both, the bird to the air, &c. These adaptations are not all equally perfect. If we could imagine that they ever were, it is certain they could not remain so for the reason that the surroundings or environment of the organisms is forever subject to change. Geological history is full of proofs of this, as we have seen. The same spot has been successively a deep salt water sea, a dry plain, a fresh water marsh, a lake and a high mountain.

Its temperature in these several states may have varied from the heat of boiling water to arctic coldness; and from being azoic at one time it may have afforded at other times conditions for the support of shell fish and sea weeds, or tropical jungles and hideous reptiles, or herbiverous mammals and prowling carnivores. While these changes occur, and we are to remember they are occuring to-day as much as ever they were, two things happen; one is the migration of a part of the population and the other is the modification of the rest. The migrations of plants and many lower animal forms is effected slowly and gradually by the birth of the new generations on that margin of the habitat which remains most favorable for its life, and the cessation of such births on the unfavorable margin. Plants whose seeds are carried by winds or currents of water may thus move many rods or even miles in a generation. Shell fish with small locomotion may move but a few yards in a generation. Vertebrate animals are equipped for more rapid migration.

It scarcely need be argued that animals or plants remaining in a changing environment will be modified by it, provided the change is not too rapid. If it is too rapid they will die.

Different species of the same genus are to be found in both very hot and very cold countries; all of which are nearly related by blood, and yet an exchange of habitat between them if made suddenly would prove

fatal to them. This proves that these species have received modifications which adapt them to the climate of their habitat. Every species is known to do better in its own climate, and if transferred will either die or become changed. The first apple trees introduced from the east into Illinois refused to bear, and the results after years of experiment were so discouraging that Horace Greeley, in an oration at an agricultural fair, advised the Illinois farmers to abandon the attempt to raise apples and attend exclusively to their reliable cereals. This advice being disregarded, as is usual in such cases, Illinois now produces apples equal to any in the country and in abundance. But they are all of different varieties from the stocks introduced from the east. The same thing is happening in Minnesota. A number of excellent varieties have been obtained totally different from anything to be found elsewhere and yet related to those of other localities. In like manner the corn of Virginia or Tennessee will not ripen in Canada, but can by degrees be modified into a variety of corn that will. The Nasturtium is said to be originally a native of Peru, where it is perennial. But introduced into the United States, different varieties grow wild as annual or biennial and rarely as perennial herbs.

In the case of animal modifications the influences of climate are equally potent, but are frequently or generally exercised indirectly by modifying the habit of the animal. Thus it is said bees taken from the United States to the Sandwich Islands, after one or two seasons, finding they could work the year round, ceased to store up honey in the hive.

The woolly Elephants of Siberia were undoubtedly related to the naked ones of Southern Asia, which was a case of simple climatic modification. But the modification of limbs and sense organs must generally be due to active habit, which is in turn determined by the circumstances of the environment including climate.

Darwin gives many examples. The fish and other animals in caves are often blind from disuse of their eyes. "In some of the crabs the foot stalk for the eye remains though the eye is gone." "The eyes of moles and some burrowing rodents are rudimentary in size and in some cases quite covered up by skin and fur," due no doubt to gradual disuse. There are several kinds of birds that cannot fly, as Ostriches, Cassowaries, the Loggerheaded Duck of South America and the Apteryx. This last is modified from the ordinary bird type, also, in having a complete diaphragm, in not having abdominal air cells, and in the circumstance of its bones not being hollow. These modifications obviously go along with the discontinuance of flight, since the lightness of bone and extra aeration of the blood are no longer required.

The effects of disuse in reducing useful organs to rudiments has already been incidentally mentioned in speaking of those rudiments which

abound in every animal and which have become functionless by disuse. Every one can recall examples of modifications of the functional power of organs by disuse or by greater use of them. Skill in the performance of any action depends upon practice or use. The eye of the Dakota Indian hunter is quicker to discern distant objects than is that of an ordinary watchmaker or tailor. The ear of a musician will detect an inharmony quicker than that of the Dakota. The hand of the blacksmith is not generally well adapted for fingering a piano, nor that of the parlor belle for shoeing a horse. Now it is always admitted that such differences in functional value are brought about by habit and use; but it is assumed that the organs are essentially the same. This assumption is incorrect. A full appreciation of the structural differences caused by habit goes a long way toward an understanding of evolution. The fact is that every movement of an organism implies waste of tissue, the repair of which depends on the environment. This process of the waste and repair of infinitessimal parts is incessant throughout life. The new parts that are incorporated in the system are in every case in some degree different from the old parts that they replace. Habit or use determines the parts in which the greater amount of waste and repair shall take place. No animal is precisely the same for two days in succession and it is chiefly the nature of his activity, in short his habit, that determines his modification. This point will be insisted upon further on.

Habit is determined in its turn directly by the necessities of the environment—the climate, soil, vicissitudes of heat and cold, dryness and moisture, light and darkness, and indirectly by these same necessities in their influence on the food supply as to quality and quantity, and yet more indirectly by their influence in the production of competitive races of animal and vegetable organisms. And when we come to speak of competition we must see at once not only that such competition necessarily exists between different races, but also between individuals of the same race. Most animals and all vegetables produce a large number of germs and seeds. If it were possible for all these to live and continue to reproduce without check, the world would long since have become too small to hold them.

The human race under favorable conditions will double in numbers every twenty years. Let the present population of the earth be estimated at 1,200,000,000, the total amount of land on earth at 52,000,000 square miles, and the increase of population to be a doubling once in fifty years. On these conditions in one thousand years, or in A. D. 2892, there will be people enough to cover the entire land area and allow each one a space of only twelve by fourteen inches to stand and make their living on. If they could be conceived to stand thus and live on air and continue to increase, the succeeding generations arranged

in tiers or stories above the first allowing five feet two inches to the story, in the year 3392 there will be 1,024 stories aggregating a mile in height occupying all the land on earth, every story having a human being on each space of twelve by fourteen inches. For a much longer time than necessary for results like those of the foregoing calculation, the conditions of life have been about as they now are, and yet the population of the earth could stand to-day on two Minnesota townships and each individual have a space twelve by twenty inches to stand on. Similar calculations are possible concerning other animal races. Unrestricted, any one of them ought soon to cover the whole earth. Marine life is more prolific than land life. Almost any mollusk or fish increases fast enough to fill the ocean in a few centuries from top to bottom and side to side and crowd the water out of its bed till it covers every continent. And yet we know there is plenty of room in the ocean. The causes that limit the indefinite expansion of the various forms of life have been in part alluded to. First, the soil and climate which directly limit the range and production of vegetation and indirectly the range of the animal life that depends upon that vegetation. It is further obvious that if two tribes of animals depend upon the same sort ot vegetation for food, it is only a question of time when the two tribes will compete with each other for that food in consequence of their natural increase in numbers. If this competition shall become a struggle for existence the stronger race will exterminate the weaker. The competition is then transferred to varieties and individuals of the surviving race, and the struggle must result in the continued elimination of the weaker members of that race. It is not possible to conceive of any mode of active existence exempt from causes of limitation and consequent struggle for existence. Even the extravagant conception of the human race living on air and building itself above the earth in layers must be limited by the extent of that air. By an extension of the calculation we find that in 1,800 years from now the race would cover the land to a hight of sixty-four miles, which is far above any practical atmosphere, and long before the attainment of that limit the struggle for life would have to begin even though life depended on nothing but air. But when we consider how many conditions are necessary to any kind of organic life, and how many organisms are struggling for the possession of these various conditions, it becomes easy to account for the enormous inroads which are made in the production of each variety by the competition of the rest. Darwin relates that on a piece of ground three feet by two, dug up for the experiment, 357 weeds came up, of which 295 were destroyed chiefly by slugs and insects. On another spot three feet by four, twenty species of weeds came up, of which nine species were choked out and destroyed by the too rapid growth of the others. Again he estimated that the

winter of 1854–55 destroyed four-fifths of the birds in his grounds. The winter of 1880–81 was as destructive as that upon the antelope in Dakota, the snow being too deep to allow them to graze.

All this struggling, whether it be against the elements of nature or against other organisms, is certain to have a selective tendency. In a contest between two, the strongest is generally the victor and secures the spoils of the victory; and these spoils are generally of some advantage to the victor and by so much a loss to the conquered. Where plants crowd and smother each other, those having the most vigorous growth monopolize the light and air with their spreading leaves and the juices of the soil by their spreading roots, and they become more vigorous by their accession, and what is very much to the point, transmit this superior vigor to their successors. The feeble plants, on the other hand, by being compelled to put up with what is left, which may be insufficient for their needs, become still more stinted and feeble and transmit a reduced constitution to their posterity. It is easy to see how in a few generations this process might cause one class to become greatly improved and the other to be exterminated. But the conquered generally have another alternative presented to them and that is a modification which amounts to a structural or habitual difference, which may or may not be an elevation of the type, but must at all events be a better adaptation to circumstances. The North American Indians have in some cases saved themselves from extermination by the whites by adopting civilized modes of life and each contenting himself with a quarter section of land, whereas in a state of barbarism he required several square miles. His resources are reduced on one side, but on the other he has adopted such a modification of habits as more than compensates for his losses, so that on the whole he is better off than before. But the Digger Indian of the Pacific Slope, who used to live in good houses and raise corn and weave blankets, when defeated and plundered on all sides by rapacious and vigorous savages, at last obtained immunity by the adoption of a vagabond life and a poverty too abject to excite the cupidity of even a savage.* This selection is the rule in civilized life as well as savage. To save himself from starvation a man will change his occupation from one thing to another, and if disappointment follows him too persistently he may change his habits of industry into those of vagrancy, and become a tramp or a thief. Or if he be unduly prosperous new habits of vicious idleness and a pampered way of life may be fastened on him. And whatever change of habit or characteristic is effected in one generation it is certain to affect and differentiate the succeeding generation. Whether a temporary habit or new anatomical condition which is transmitted by heredity shall become a fixed character-

* The Digger is said to be a degenerate relative of the civilized Aztecs.

istic of the breed will depend on whether the habit be continued or the new anatomical condition be useful and used by the offspring. A continuance of the conditions through succeeding generations are necessary to fix any new characteristic. It is constantly remarked by naturalists that the latest modifications of type in any race are more liable to variation than the older ones. In the human race the latest anatomical modifications are to be found in the relative lengths of the legs and arms, formation and amplitude of their muscles and particularly in the organs of speech and the development of the cerebral hemispheres. So I think we will find more cases of congenital reversion or arrest, as well as more cases of superior development to relate to these parts than to the parts which we possess more in common with the lower animals. Many cases of idiocy and imbecility are on record, which have resulted from the transmission of temporary cerebral debility on the part of parents. One case is cited of an idiot born to parents who were both drunk when he was begotten, but who were ordinarily intelligent when sober. Another case is given of an imbecile born so in consequence of a strong mental disturbance of the mother from seeing an idiot during the period of gestation. "A medical practitioner of Douglas in the Isle of Man, mentions the following case: A man's first child was of sound mind; afterwards he had a fall from his horse by which his head was much injured. His next two children proved to be both idiots. After this he was trepanned and had other children and they turned out to be of sound mind."[1] It is often observed that children born to foreign parents of the working classes after their immigration to this country are brighter and more intelligent than the children of the same parents born before they left Europe.

Childhood is said to be the impressible age. Lessons learned and habits formed in childhood are more fixed than those of later date. But the embryonic or prenatal state is far more plastic than childhood, and it is while in this state that all the essential parental characteristics are impressed upon it, whether such characteristics be permanent or only temporary to the parents. The plasticity of the embryonic stage is especially observable in fish culture, the natural conditions not being precisely imitated in artificial hatching. The number of malformations among the embryo of the artificially hatched salmon, trout, whitefish, &c., is sometimes so great as to make serious inroads on the profits of the business. A very common monstrosity consists in having two heads, another of having a double backbone and spinal cord. In some cases the sense organs or the locomotive organs are defective, in others there is an anomalous development of the intestinal system. Such malformations are common among carp and still more so among gold fish; and

[1] Combs' Constitution of Man, 160.

the Chinese taking advantage by selection of these freaks have managed to develop a number of special races, among which are some having an extra number of tails.[2] These facts illustrate well the possibility of life inhering in anomalous and unusual forms. Yet these forms would not in a state of usual conditions be able to maintain themselves and perpetuate their peculiarities in a posterity. If left to themselves "they sooner or later succumb in the struggle for existence." But when proper conditions are artificially supplied almost any sort of monstrosity is able to propagate itself. In an ordinary state of nature it is obvious that one generation cannot be allowed to vary greatly from its predecessor, because its environment is so similar to that of its predecessor that any freaks or departures from the ancestral type, if too great, become a burden instead of a help, and the individuals who happen to labor under such burden fail in the struggle for existence and so do not perpetuate their peculiarities.

But on the other hand, it is obvious that any peculiarity or variation from the ancestral type that is advantageous to its possessor, and better fits it for making its way against competition, will make it stronger also to perpetuate such peculiarity in its posterity. Because use confirms and crystallizes habit, and it is habit or constant functional activity that first modifies and finally fixes and consolidates a peculiarity of form; and when any peculiarity of form becomes fixed it becomes regularly and normally transmissable, and from being an individual monstrosity becomes at length a specific or race peculiarity. But most of the variations from a family or race type that occur in individuals are of an extremely slight description and from the uniformity and wide extent of similar causes are apt to be alike in many individuals at the same time; and from the persistence of the causes the variations are apt to be continuously supplemented by additions in the same direction, making the tendency not only to confirm the variations but to increase them.

As an example, suppose a certain island to be inhabited by a race of rabbits that browse upon the herbage, and a pack of wolves whose only resource for a livelihood consists of the rabbits which they hunt. The process of hunting calls into play certain activities—a keen sense of sight to quickly spy the prey, and quick senses of hearing and smell to detect the prey when not in sight; speed of limb to enable the hunter to catch the prey, and sagacity to cause the hunter to place himself between the prey and his burrow or safe retreat, or to place himself on the leeward side of his intended victim, or to reduce his distance from him by silently creeping up under cover. No individual can exercise these several faculties without strengthening them, any more than he can suf-

[2] Harper's Annual, 1874, 294.

fer them to fall into disuse without their deterioration and decay. So we may suppose that all the wolves by reason of their hunting the rabbits would become possessed of keener organs of sight, smell and hearing, more vigorous legs, and larger cerebral hemispheres than they had at first. On the other hand, the rabbits, by the exercise of like faculties for their self preservation, develop their organs of sense, locomotion, and reflection. The reproductive qualities of the rabbits are very great. Their numbers double at least every three months and if unchecked they would soon reach the limit of their food supply on our island. But of course their increase is checked by the inroads of the wolves. Every day the wolves select certain of the rabbits for their dinner, a selection governed by the inexorable laws of necessity. For each wolf takes such rabbit as he can get, and the captured ones will obviously be those least alert, those having the dullest senses, those least active of limb, those most debilitated by disease or worn out by age, and those most conspicuous by reason of their color or their odor. This daily selection of the weak and inferior to die is also a selection of the strongest and best to live and transmit their superior qualities to their heirs and successors. Thus the selection by the wolves tends to improve the stock of rabbits, just as the limit of their food supply would tend to improve them if there were no wolves. For as soon as the limit of the food supply were approached there would be a struggle among the rabbits themselves for their food, the strongest and most active obtaining it and leaving the weaker to succumb to want.

A rabbit pursued by hounds has been known to transfer the pursuit to another rabbit. He would lead the chase near the retreat of rabbit number two, and suddenly leaping upon his seat would crowd No. 2 off and compel him to take flight before the dogs, while No. 1 remained unobserved on the usurped seat.

Notwithstanding the rapidity with which rabbits increase it is not great enough to allow for the unchecked increase of wolves. Say the latter double every year while the rabbits increase eight fold. But a wolf must have at least 100 rabbits a year or starve; so for each new wolf there should be 100 new rabbits, and there are only one-twelfth that number. The result of the struggle among the wolves for this limited food supply must result in the same way as among the rabbits, in selecting the most wily, alert, observing and active wolves for survival and the transmission of their qualities, while the *hindermost* must always be the ones to succumb. The details of the struggle for existence are of various kinds. Those that fail to secure food starve outright. Others are killed in contests to maintain the ownership of what they have obtained. Others are reduced to a condition incompatible with the production of vigorous offspring and so run out.

The law of organic existence necessarily involves a perpetual selective struggle. The existence of no organism is possible except on condition of the destruction of some other organism or the repression of some other organic possibility. The selection made necessary by the nature of things is influenced by every circumstance in the environment either directly or indirectly. The slightest difference between two animals might determine the question of the survival of one or the other, such for example as the thickness and warmth of the hair or fur covering, which in an unusually cold winter might in one case be just sufficient to save its owner from freezing, in the other, not. A shade or two difference in color might operate the same way, since the least conspicuous of two beasts of prey could get nearer to his victim without being observed. And on the other hand the most conspicuous victim would be the first to be caught.

Darwin observes that while it is easy to tame an animal it is exceedingly difficult to get it to breed under confinement. This is especially true of carnivorous birds. The same rule holds with regard to plants. Taken from a natural state and subjected to cultivation, at first although they grow with vigor, they refuse to bear seed. When civilization is too suddenly imposed upon savages we see the same effect in the reduction of their breeding powers. The Sandwich Islanders and native New Zealanders are conspicuous examples, and are being rapidly civilized out of existence. It has been assumed sometimes that the decrease of these populations was due to the introduction and prevalence of civilized diseases and vices—which carry them off—but better information shows it to be due to the decrease of the birth rate.

The imposition of so-called "culture" upon civilized communities appears to have the same effect of reducing fertility and lowering the birth rate in the cultured class; so much so that its perpetuation depends on constant reinforcements from the ranks of the uncultured classes. In these cases there are introduced into the environment new stimuli which do not find in the organization any corresponding anatomical (including cerebral) differentiation from which these stimuli are reflected as a matter of use and habit. Consequently these stimuli act by exercising an unusual degree of differentiating or developing influence, causing a continuous growth in the organism. It will be shown hereafter that a checking or cessation of growth more or less complete in other directions is essential to the precipitation of vital energy in the form of reproductive force. It further illustrates what has already been mentioned that every new feature of a changed environment begins to work out new features in the organism and where worked out too fast tends to exterminate that organism.

CHAPTER XVII.

SEXUAL AND ARTIFICIAL SELECTION.

It has been stated that the prevertebrate types in the ancestral line to which our race belongs were hermaphrodite. The first differentiation into male and female occurred in an animal equivalent to the Amphioxus, and consisted of a differentiation of the reproductive organs only, which being internal left the male and female indistinguishable. The female ova and the male spermatozoa being thrown into the water found each other without care or intervention from the parents. But in the course of evolution there came about a condition of things in which greater certainty in the impregnation of the ova became essential, the number of the ova diminishing with the increase in the race development and with the certainty of the impregnation and safety of egg when impregnated. When the impregnation of the ova became internal in the body of the female, as in reptiles and mammals, a choice or selection of males became possible. Especially is that the case when the services of the male are not required in the care of the young, for then polygamy is possible and a single male may mate with several females to the exclusion of several males. The selection of this single mate is sometimes made by the females interested, but more often is settled by contest among the males, the largest, most vigorous and active usually coming out ahead, and becoming the father of the next generation. This sort of selection will tend to the general improvement of the race in both sexes, since the qualities of both parents are transmitted to both the male and female offspring. Nevertheless there are qualities which transmissible through either sex, only appear and are developed in one. Obviously the exclusively male qualities will appear only in the male offspring and the female in female offspring. But along with these are collateral and parallel developments that follow sex more or less closely and only appear in the proper sex. This law of collateral development will be mentioned further on. By it the qualities of courage and pugnacity, and the accompanying size, strength and anatomical peculiarities by which the males are selected to be parents, are inherited by the male offspring. The infinite repetition of this selective process accumulating masculine advantages, without a parallel competition among the females, amply accounts for the difference in size and strength between the two sexes throughout the mammalian class, especially the polygamists of the class; also for the superior development in the males of such weapons of war as spurs and horns, and such aids to defense as the mane of the male lion and the shoulder pad of the boar. According to Darwin the male alligator and salmon contend for the possession of the female.

Among the most remarkable examples of sexual selection are the seals, in most of which there is great disproportion in the size of the sexes. In the Falkland Otary or Fur Seal of commerce the full grown male according to Weddell measures six feet, nine inches in length and the female only three feet, six inches. "*It is polygamous in the proportion of one male to twenty females.*"[1] The Inia, a Cetacean mammal is also remarkable for the disparity of sexes, a female measuring about seven feet in length and a male about fourteen.[2] The female orang is smaller and the female gorilla is much smaller than the male. The disparity of the sexes in our own race is due in the first instance to the practice of polygamy just as in the case of other mammals.

Among some animals the females exercise an elective power over the males based upon the attractive personal qualities of the latter. This is true especially of birds, and no doubt the peculiar and generally superior plumage and singing qualities of the male over the female birds is due to the infinite accumulations of feminine preferences. The inequality between the sexes is therefore a necessary consequence of that division of labor by which the ovary and its products were assigned to the keeping of one individual and the testis and its products to another. And such division of labor and the differentiation of parts to suit its performance is as we shall see, the sum and essence of evolution.

Different races of animals exercise upon one another very considerable powers of selection. Geology shows that there has always been some one dominant race at the head of the animal kingdom. The dominant race has been superior to the others in power, has exterminated those of them that were rivals, fed upon others suitable for food and caused all with which it came into contact to assume new modes of defense and habits of life. The accession to power of a new dominant race has always been followed by a dwindling in the number and generally in the size, power and importance of the preceding dominant race. Thus the accession of the Cephalopod Orthoceras in the Silurian times was followed by the dwindling and disappearance of the Trilobite, which had been the ruling race. The Orthoceras retired and took a subordinate place when the vertebrate Selachians came upon the scene.

In Mesozoic times the great Saurian reptiles became the dominating types and the seat of the dominion of the earth was gradually transferred from the sea to the land. The great Saurians retired on the accession of the land mammals, the Elephant, the Stag, the Bison, and the great Carnivores, and these in turn have given way before man. Aside from or in addition to the primary action of the general forces of nature in developing these new types and in giving a backset to the old ones this secondary action of the types upon one another is of very great import-

[1] Cuvier Animal Kingdom, P. 87. [2] Cuvier 136.

ance. The disappearance of an old dominant type is hastened not only by the adverse effects of new climatic and food conditions, but by the natural hostility of the incoming new type. If the old one is good for food it will be eaten; if it uses the same sort of food it will be in competition with the new comer and if less vigorous will be rapidly destroyed, and in the process the victorious party will itself undergo modification. If a race of animals suitable for the food of another is entirely consumed and exterminated by it, the *survivors* must adopt a new bill of fare, which may tend to still further modification of themselves.

The action of man upon other animal races is probably more effectual than that of any dominant type that has gone before, although in the same direction. He has exterminated or contributed to the extermination of almost all the great herbivores and carnivores that ranged over Europe and America in Tertiary times, and it is only a question of time when he will do the same in Asia and Africa. But he has selected for survival a great number of tribes that he finds he can make useful to himself—the Horse, Ass, Camel, Elephant, Dog, Lama, Deer, Sheep, Goat, Hog, Buffalo, Ox, Cat, Chicken, Goose, Pea-fowl, Guinea-fowl, Turkey, Duck, Pigeon, Rabbit, Ferret, Falcon, Cormorant, &c., have all been domesticated wholly or partially, and made to contribute to the needs of the dominant race. Many of these have been subjected to artificial differentiating causes, and then to repeated and long continued selection, by which numerous varieties and breeds have been produced, differing greatly from their original stocks and from each other. The art of breeding cattle, horses, sheep, dogs and various fowls has been known and practiced from time immemorial. The patriarch Jacob understood both the causes of variation and the theory of selection—according to Genesis, chapter thirty—more than 3600 years ago. Great stimulus has been given within the present century to artificial selection, and rapid progress has been made both in actual results and in the theory of it. It is now said that a breeder of sheep, for example, may chalk out on a wall such form as he prefers, and may, by selection, in a few generations, copy the pattern in the form of his animals. Of pigeons a skillful breeder said he could produce any given feather in three years, and a given form of head or beak in six years. Darwin asserts that there are not less than twenty varieties of domestic pigeons which if wild would be classed as so many species, which have all been artificially differentiated by selection from the single species of Rock-pigeon—Columba livia. The variations from the original stock are very great, extending to form, size, color, habits, and anatomical structure. The Fantail has thirty or forty tail feathers, while the original number is twelve or fourteen. "The Jacobin has the feathers so much reversed along the back of the neck that they form a hood." The

Pouter has a much elongated body, wings and legs, and an enormously developed crop, which it puffs out with air. The Tumblers have a habit of flying in a compact flock high in the air, and there tumbling heels over head in their flight. The Carrier, the Runt, the Barb and others, all differ from each other in various ways.

The differences in the skeletons of pigeons changed by artificial selection and cultivation, are of the most marked sort. There is great difference "in the number of vertebræ and ribs, in the size and shape of the gaps in the breast-bones," and in the clavicles or wish-bone, in the head and facial bones, the lower jaw, &c. In the Fantail, which carries its tail feathers erect and even curved forward so as to touch the head, the oil gland is quite aborted. These radical anatomical differences are proofs of the formative action of habit on the organism.

A new species of rabbit has arisen on the island of Porto Santo, near Madeira, since the year 1419, at which time a few tame Spanish rabbits were left there. They are extraordinarily wild, of a rat-like shape, and peculiar color, nocturnal in habit and will not breed with the European species from which they were derived.

The same effects are seen not only in the selective action upon the domestic animals but upon plants. Almost all the cultivated fruits and other vegetation have been greatly altered from their originals by repeated selection. This selection has been accomplished generally without any well defined or highly scientific ideas or plan, but simply by planting the seeds of the most satisfactory plants—an obvious thing, even to savages.

This artificial selection, with its accompanying improvement of plants and animals, is made by man for his own advantage. It shows the flexibility of the conditions of life, and how there may be a constant accumulation of variations in one direction, amounting to specific distinctions at first and generic distinctions at last.

Artificial operations are, it is true, only a subdivision of natural operations, but artificial selection differs from the other natural selection in the fact that, in the latter, the changes in the form of the organism are made exclusively for its own benefit, while in the former, changes are made for its benefit so as to include man's benefit. In the latter, the organism maintains its struggle with its environment alone, in the former, man constitutes a part of its environment and a very advantageous and important part. For without doubt none of the proteges of man would be the same without his help, but would speedily revert toward the condition from which he has developed them. Witness the hogs of Missouri, turned out to make their own living in the woods. Long of limb, tail, ears, and snout, they are sinewy, enterprising, active and hardy, able to climb an eight rail fence or crawl through a four

inch crack. A pampered Berkshire or China pig would stand no show in an unaided competition with these "razor backs." Natural selection must invariably encourage and increase those characteristics and peculiarities that are of advantage to the individual in preserving it and perpetuating its breed. When a hog is under human domestication, the points tending to its preservation are perfect digestion and assimilation, an ability to get fat quickly, and a form upon which the flesh can be packed with the greatest economy of room, and which is least adapted for those activities which convert food into motion instead of flesh. In short, very different qualities are required to preserve the hog while in domestication from those which best preserve him while in the wild state, but the principle of the selection is the same in each case; and those animals having points which best adapt them to live, all the conditions of their environment considered, are the ones most likely to survive as a race, and transmit their qualities to a posterity. Artificial selection, therefore, is only one form of natural selection and does not in any sense subvert or suspend the law of competition and struggle for life and the survival of the fittest.

By the term *fittest* must be understood not necessarily the highest in development, but having the best adaptation to the environment, and as before stated the alterations sometimes naturally selected for the preservation of a race actually reduce the race in its anatomy and function to a lower plane. For example, the Penguin whose wing is reduced to a fin-like rudiment useless for flying but valuable in swimming and covered with feathers that are but little better than scales, and whose feet can only push him along the ground on his belly—not carry him—and whose bones are filled with marrow instead of air, is probably a degenerated bird partly reverted to the Reptilian type. (Fig. 74.)

FIG. 74.—*King Penguin* of Patagonia.

In the Madeira Islands are about 550 species of beetles. The wings of 200 species of these are so far aborted as to be useless for flight. All the species of twenty-three out of the twenty-nine genera found there are in this condition. Darwin plausibly traces the cause of this remarkable fact to selection by the wind which tends to blow out to sea those which were most addicted to flying, thus gradually reducing the

numbers of the flyers and preserving those having defective wings, or disinclination to fly and so producing species with reduced and useless wings. On the other hand, those beetles which must fly in order to live, as those feeding on flowers, have been improved in their wings, since in their case those having the feeblest wings have been blown out to sea and perished and the strongest selected to live. (Selection of Species, 124.)

It is difficult in this as in most cases to determine how much is due to the direct action of dynamical causes and how much to their indirect agency through habit—use or disuse. The wind would cause the beetles to disuse their wings as much as they *could*. The ground feeding beetles *could* live without using wings at all, and as the wind made their wings a burden, disuse would in time reduce them to rudiments, selection picking out for survival those most reduced.

Amongst the human races the savage and the civilized are largely in each other's way—usually to the great grief of the former. The competition of individuals in civil life is largely compensated by coöperation and mutual help in procuring what they all want. But when a differentiation takes place which destroys coöperation without destroying competition, the result must be a struggle in which the weaker party will perish. The only ways in which inferior races have managed to live upon the earth are either to become useful to the superior, to amalgamate with them and thus *become* superior or to get entirely out of their way. For examples in point consult the history of the Magyars, the Basques, Laps, Africans, &c. We may reasonably suppose that many "connecting links" have been disposed of by superior races, and made to entirely disappear either by annihilation or amalgamation or a combination of the two.

The theory of selection is curiously confirmed by facts in relation to what is called mimicry, and the protection which various animals derive from their color or form. As a general thing, those that are the most gay, attractive or conspicuous are provided with some means of defense, as a crustaceous shell or armor, a sting, an offensive odor, as in many insects, the skunk, &c. Those that are not conspicuous and depend upon that circumstance in whole or in large part for their security are as a rule not provided with other means of defense. The theory of this is, of course, that not being seen they have not been attacked and not therefore defending themselves, no weapons of defense have been differentiated and selected in their case, while those that have succumbed to such pursuit as they may have been exposed to have been the most conspicuous of their tribe, the least conspicuous being thus constantly selected for survival. Thus the constant tendency is for animals as a part or perhaps the whole of their defense to become colored like the

locality they most inhabit, as in the case of quails, rabbits, deer, &c., as well as many insects. But it is still more remarkable that many creatures imitate not the color merely but the form of others having better modes of defense. Real wasps are quite conspicuous, but have a weapon in their tail which is a good defense. Species of the Sesia Aegeriidea have no sting, but they resemble small wasps so closely that everybody is afraid of them. The Butterfly Heliconia is avoided on account of its bad smell. Three other species which do not enjoy the ownership of a bad odor, viz., the Leptalis, Erycina and Ithonia are very like it in appearance, a circumstance which causes them to be avoided by mistake. (Semper.) Such cases of imitation are extremely numerous among insects.

There are many cases in which insects, such as locusts and grasshoppers, so closely resemble in color and form the green leaves of the trees they inhabit as generally to escape notice. There are also a good many cases of protective resemblances among the vertebrates, where harmless snakes look like poisonous ones, and certain harmless birds look like birds of prey. No doubt there are cases of resemblance in animals arising from causes no way related or dependent on each other, and which may be called accidental resemblances, but it is evident that "protective resemblances" however small will sometimes preserve their possessors, and this constitutes a mode of selection.

CHAPTER XVIII.

PERIODICITY.

The only distinct phenomenon attending vitality which seems to separate it from other forms of motion and chemism, is its power of going on, of continuing its essential qualities under varying forms—an egg, embryo, child, man, egg—thus in four terms completing a cycle of forms each of which in disappearing gives rise to its successor. This uniformity of recurrence is the only thing about it that is characteristic. Growth is not exclusively characteristic of live organisms. Crystallizations, dendritic formations, chemical unions, electrolysis—all chemical reactions are examples of growth, which is the quasi spontaneous aggregation of matter under its varying affinities and their varying degrees of power.

But here is a periodicity—a going on in one form for a time which is more or less definite, then a change and another period of definite duration, &c. Periodicity goes with everything organic, and is evidently originally derived from and dependent on the general periodicity of the great molar movements of the general universe. The growth is

due to molecular motion, its periodicity to molar or motion in the mass—planetary motions. The most obvious of these is the alternation of night and day by the periodic revolution of the earth on its axis. The effect of this on plants is to periodize the action of light upon Chlorophyll. All green leafed plants, or plants containing chlorophyll, in the day time decompose carbonic acid and form starch to be carried into their tissues. But in the night the sunlight, which really does this work for the plant, being absent, the process of making starch is suspended. Daylight is used by the plant to procure the means of livelihood and during the night the material secured is turned into tissue. The same is the case with the animal, although not in the same proportion. On account of his constant movements and work done in the day time he constantly consumes his tissues and gives them off to the air in the shape of carbonic dioxide. But the greater part of this waste is due to the external work he does, while the waste which takes place in the night is due to the internal work of repair, just as it is in plants. All work is done at the expense of tissue. External work is generally done during consciousness, but whether it all is or not, at any rate consciousness itself *is* work (as will be shown elsewhere). It follows therefore that repairs cannot go on so well during consciousness as during unconsciousness. Therefore under the law of selection, there would be a tendency to reduce animals to unconsciousness during repairs. Hence we have sleep, or the state of unconsciousness which is necessary to the discontinuance of work, whereby the general energy of the organism is devoted to the repairs of wasted tissue. The causes that fix night as the general time for sleep are as obvious in the case of animal life as in that of vegetable, although not precisely the same, except perhaps to a limited extent. The exceptions are all accounted for in accordance with the law, which is that light is productive of work, proven in the case of plants being awake at night in presence of artificial light and sleeping in the day time when confined in artificial darkness.

The revolution of the earth around the sun, which coupled with the inclination of the polar axis produces the alternations of the seasons, is another periodical movement no less momentous than the first. By this, in the temperate zones a period is reached every year in which the temperature is too low to allow of the chemical reactions required for growth, viz., the decomposition by light of carbon dioxide and the decomposition of starch and sugar by diastase in the tissues of plants. During the warm months, therefore, myriads of herbs pass entirely through the terms of their cycle of existence, beginning with seed, continuing through germination, growth, fertilization and maturation of the new seed. These are called annual plants. Others are biennial, growing one season, stopping during winter and forming their seeds the

second season. Others last a term of years, producing leaves and seeds each season, which drop off leaving only the stems and roots or perhaps only the roots to retain the vital principle of the individual through the term of years. We can easily see how the limit of annual herbs is compassed, and how in fact cessation of growth of the leaves and seeds must take place, and how they must fall from the plant in the end of the summer.

Animals, too, are required to become newly adapted to the change in temperature every fall and spring. Many animals hibernate, or go into a winter sleep, becoming more or less torpid in the winter, in which condition their tissues undergo comparatively slow waste, their respiration being much less rapid than in summer. Frogs in winter suspend a large share of their vital activity. Their blood has been proved by experiment to be destitute in winter of the diastasic ferment or digestive juice which it has in summer. Its waste and repair are both reduced to a minimum during the cold season.

In some tropical countries alligators burrow in the mud during the dry season, remaining some months in a state of torpidity or summer sleep. and emerge at the approach of the rainy season. The annual migrations of birds, fishes and other animals is also due to the annual periodicity of climatic changes. The necessity of the germination of seeds in the spring is obviously because they need the coming summer for growth and maturation, and this necessity selects such as can do this. The same necessity selects the spring and early summer as the best season for the mating and sexual pairing of many of the animals. Birds by laying their eggs in spring and rearing their young during the summer bring them to a self-supporting condition by winter, so that they can provide for their own wants or are able to migrate to a milder climate with their elders. The duration of gestation with many of the larger mammals is such—from 7 to 11 months—that by the pairing in early summer the birth of the young is brought about in the following spring, and the young animal has its youthful nursing days in the time of year most favorable for its strong and vigorous nourishment. Such an advantage as this would be cause for selection.

Menstruation is another periodical phenomenon—monthly in man as the term implies, and connected with the development of ova. The females of the Cynomorpha (Doues and Baboons) are subject to the menstrual hemorrhage. According to Buffon this is common among the Ape tribes. Both Apes and men have, however, outgrown the domination of the seasons in respect to the birth of the offspring, as in all the tribes they are born at all times of the year.

But with birds the season appears to be omnipotent, even to the regulating of their physiological condition sexually with great precision in

respect to time. The testes of birds are situated internally above the kidneys near the lungs. During the mating season they attain an extraordinary and enormous development.

Fig. 75. *Testes of House Sparrow at different periods.*
I.—January.
II.—Middle of February.
III.—Beginning of March.
IV.—Latter end of March.
V.—Middle of April.
(*After J. F. Brandt.*)

The testes of the house sparrow which are one-twelfth of an inch in diameter in January become one-half an inch in April, or 216 times as large.

During the mating season the testes of Rodents come down into the groin. The Shrews (Insectivora) have a peculiar gland on each side just under the skin which at the same season has an activity peculiar to itself in exuding an odorous fluid. The hand of the frog has four fingers and one of these it uses as a thumb. This thumb in the male is furnished with a spongy swelling which enlarges during the breeding season to aid in grasping the female. The down on the breasts of female birds disappears during the season of incubation—is not plucked out but drops automatically—to allow the bare warm skin of the mother to come in contact with the eggs. Ordinarily ducks and drakes differ from each other in color, but immediately after the breeding season the coloring of the drake changes to resemble that of the duck. This change is not accompanied with the loss of the feathers—which occurs at another time—the moulting season.

The feathers of birds are in general renewed in autumn only, but in some cases in the spring also. About the commencement of the breeding season some birds undergo a change of color without moulting. When this takes place as in certain Gambets, an arctic bird (Totanus), the coloring matter is often entirely absorbed previously to the autumnal change of feather, and in some double moulting species, as the Golden Plover, it commonly happens in spring that the coloring secretion tinges the old feathers that are loose and ready to drop off, thus proving that a circulation obtains in the pores of the feathers even up to the period of their being naturally cast. (Cuvier, P. 146.) There are many other cases of special phenomena attending animal reproduction, the periodical recurrence of which had its origin in the periodical recurrence of the seasons and the movements of the planetary bodies. For the reason that the seasons are different from ours on all the other planets it is not possible that animal life on them should be like what it is here; and as our own climates change, life will continue to be changed in the future as it has been in the past.

CHAPTER XIX.

EFFECT OF TEMPERATURE.

The effect of heat and cold on organisms was alluded to in connection with what was said on periodicity. The periodic recurrence of changes in temperature induce periodic changes in organic habits of both vegetables and animals. Some further inquiry will show the proximate causes.[1] Temperature expresses the degree of molecular vibration going on in the constituent particles of a body. The higher the degree of temperature the greater isthe molecular activity of the particles, and the further apart are the molecules separated from each other. Hence a heated body expands, and the attraction of the molecules of which it is composed, for each other, is either lost or neutralized by an opposing force. The molecules of all bodies require to be thus shaken from each other's embraces before they can be brought into new combinations with other bodies. The degree of temperature at which the chemistry of the vital functions can be carried on depends on the complexity of the molecular constitution of the organs in which the function is performed, and which differs greatly in different organisms, and within bounds largely on habit, as between those organisms which appear to be identical in structure. Again some of the functions necessary to a continuance and reproduction of vitality may be carried on at a temperature that causes a suspension of others. The general limits of life are between the freezing and the boiling points of water, 0° and 100° centigrade or 32° and 212° Fahrenheit. But no organism can carry on *all* its functions very near either of those limits. There are certain organic germs, however, that it requires more than boiling heat to destroy, and the eggs of some fish and insects, crustaceans, bryozoans and sponges, are not destroyed by a temperature below freezing. But in both cases probably the temperature of the organism is not changed quite to that of its medium.

Both animal and vegetable protoplasm is killed at from 40° to 50° C., but some crustaceans and the larvæ of insects and some algæ live in water from 50° to 60° C. Infusoria possess in the interior of their bit of protoplasm a contractile vesicle which contracts and dilates with some regularity at its normal temperature, which is between 15° and 30° C. At 15° the pulsations were observed to be fifteen per minute, and the number increased with the temperature. But at 10° the pulsations were reduced to from 2 to 9 per minute, the different species of these little

[1] Many of the facts mentioned in this chapter and the next I have culled from Karl Semper's "Animal Life."

creatures having different powers of resistance. At 5° their pulsations still continued, but at 2° or 3° all movement ceased. These animals have two kinds of Cilia, those which produce a rotary motion and are involuntary, and those which move backward and forward and are voluntary or subject to the will. The involuntary movements continue up to a temperature of 42° to 45° C., but the voluntary movements cease at 40° and become wild and purposeless at 35°. From the torpor produced by 5° C. these specks of vitality will recover if it be not too prolonged. The pond snail Lymnæa Stagnalis will not die in a temperature close to freezing, but will not assimilate food and grow below a temperature of 12°, the normal temperature being 25° C. If raised in a low temperature they are dwarfed in size but not injured in their reproductive powers. In fact, the best temperature for reproduction is much lower than for growth, and the spermatozoa and ova do not seem to be formed till the growth of the other tissues is checked, which occurs in the winter and early spring, when the reproduction takes place. Cold as a rule has a tendency to dwarf all organic growth, both vegetable and animal, the degree of temperature to be called *cold*, however, being very different in different organisms. But the checking of growth affects some tissues sooner than others. The reproductive powers for obvious reasons are usually among the last to suffer from a decline of vitality. Reproduction is the great conservative function, appearing, as the culmination of all the rest, and when they receive their first check or halt in development. The check in general development caused by the cold of winter is followed in a great many cases by the formation of reproductive germs. The eggs of frogs and snails are formed in the ovaries in the winter at a time when the animals eat little or nothing and while their temperature is too low to assimilate food. They are not spawned, however, till the temperature begins to rise in the spring. But even the immature young or larvæ of many animals are able to reproduce if their growth be checked. It is to be observed that the exhaustive effects of excessive heat are similar to those of excessive cold. Growth and development may be stinted and checked by one equally with the other. Accordingly we find that half grown land snails will reproduce when their growth is checked by cold, and they will also reproduce when their growth is checked at the age of six months by intense heat. Then after the summer is over, on the approach of cold weather, the animal being nearly or quite grown, another deposit of eggs takes place. This reproduction by stinted youngsters is by no means rare; it happens to the larvæ of worms, Ascidians, Mollusks and even vertebrates, as in the case of the Axolotl.

Among crustaceans, insects, rotatoria and others there are many species that lay two sets of eggs, one in summer and the other in

autumn, designated respectively summer and winter eggs, and these two kinds of eggs when hatched turn out animals quite unlike each other.

The history of the plant louse Aphis is also very remarkable. The eggs hatched in the spring produce only females. These females lay eggs without male impregnation which likewise hatch out only females, and this *parthenogenetic* process continues till the cool weather of fall. Fourteen generations of unmarried females have been produced thus in one summer. The cool weather of autumn causes some of the eggs to hatch males, and the last batches of eggs are fertilized by these males. These are called winter eggs. They endure the vicissitudes of the winter and are hatched in the spring to repeat the process. This parthenogenetic process can be kept up indefinitely. Reaumur produced over fifty generations thus without males in the course of three or four years by supplying artificial warmth in winter, with proper food.

It is known that the checking of plant growth, which happens to some by the heat of summer and to others by the cold of autumn, is followed by the formation of the seeds and the pushing forward of the buds for the next year.

The very general mating of animals in the spring in the temperate zones, is, no doubt, very largely due to the effect of the preceding cold of winter, in checking the general growth and diverting the vital energies into the channel of reproduction; so that, when upon the rising temperature of spring there is a renewal of activity, it first takes that form.

This inference is strongly confirmed by the fact that the periodicity of reproduction is quite lost amongst men and some of the domestic animals who are artificially secured against the effects of climatic changes. And it does not obtain in latitudes of even climate the year round.

In the Phillipine Islands Semper could at all times, summer and winter, find eggs, larvæ and propagating individuals of the land mollusca, insects and other land animals. In man sexual maturity is attained earlier in the tropics. In Egypt and Cuba girls are mature at twelve. Swine also mature early; a boar at Manilla being capable of reproduction at the age of three weeks. It appears to me more probable that this early maturity is not due to the shock or check of sudden heat, such as might and does take place in the temperate zones upon every change from spring to summer. The climate is even and generally prolific, and pushes all sorts of organic bodies to rapid completion, since they can grow both winter and summer, and this maturity of the reproductive powers comes here as elsewhere on the heels of the others and after they cease to absorb all the vital energy; but in this case because they are mature, while in the other cases it is because they are checked while yet immature.

The animal functions and activities, including consciousness and all the conscious actions, are supplementary, in the animal economy, to the vegetative functions, and are, consequently, of secondary importance.

The normal remedy of nature for vital exhaustion is the suspension of these animal functions temporarily. This is done every day in sleep. During sleep the waste of brain, nerve and muscle tissue is largely suspended, and whatever surplus remains to the vegetative organs after their own nourishment is secured, is transferred to the repairs of the animal organs. But if during sleep there is no surplus of food and energy above what is required for the vegetative parts of the organism, the animal parts may remain unrenewed indefinitely, or until their functions are required to assist in securing a new supply of food for the vegetative parts. But as long as the vegetative functions can run without the animal functions they will do it, and the sleep will continue. When the organic system is subjected to a temperature either above or below the normal, more or less exhaustion ensues, and the tendency is to curtail expenses by cutting short the supply to the animal functions. So we find lethargy and sleep induced by both the cold of winter and the heat of summer. Everybody can testify to experimental knowledge of this, although the human race has become largely independent of the weather. Exposure to the cold of a chilly day is succeeded by drowsiness. A slight lowering of the temperature in the tropics makes the natives sleepy. All the warm blooded animals are made sleepy by the cold, and many of them sleep most of the winter in the temperate climates—among these are the Bear, and most other Plantigrades, Bat, Hedgehog, Zizil, Marmot, Dormouse, Hamster, Ground-squirrel, &c.

In some, the temperature is reduced almost to freezing, as in the Zizil and Marmot, whose temperature goes as low as 43° F., the waking temperature being 101° to 103° F.

Nearly all the cold blooded land animals, as Snakes, Toads, Lizzards, &c., also Turtles, Eels and Insects, are rendered torpid by the cold, their temperature generally keeping near that of the air. Reptiles and Amphibians at best live very low and slow, their respiration and digestion being very inactive. In the winter sleep both are reduced to a minimum.

All of us can likewise testify to the drowsy effect of summer heat. Our fellow creatures are affected in the same way, and many of them make a season of it by going into a summer sleep. The Tenrec of Madagascar, a relative of the Hedgehog, does this, and so do numerous insects, spiders, snails, toads and lizzards, the Crocodile in some countries, and most of the land Mollusks around the Mediterranean Sea.

Exhaustion of tissue may proceed from two causes: overwork, and under-feeding of the tissue. When the system is contending against

cold, a large part of the food must be simply burnt up to keep the heat of the body up to the temperature necessary for the chemical reactions of digestion, respiration, &c. Consequently more food is eaten in cold than in warm weather. If the digestive organs have not the capacity to digest food enough to more than warm the blood, the tissues remain unfed and torpor results. Under the influence of excessive heat the first effects are very different. None of the food is required for fuel, but it becomes fuel notwithstanding; for every process of organic action that includes the formation of carbonic acid gives out heat, so that whatever is done, even the digestion of food, tends to increase the already abnormal heat. The greater the heat the more rapidly are the tissues torn down, and therefore the greater the waste, since more of the energy developed by the combustion goes to make useless heat that must be got rid of, and less is left to be converted into work—in the muscles and brain. It is like burning fuel in a stove instead of the engine furnace; it makes heat that cannot be converted into work, or it is like burning it in a defective furnace that allows the heat to escape into the air instead of turning the water into steam. The fuel is burnt up too fast to be utilized and reduced to work in the system. Add to this, that a large part of the energy that is turned to work, must be expended in efforts to reduce and rid the system of the surplus heat. Evaporation is a cooling process that goes into operation wherever there is water in contact with air, unless the air is already saturated. It requires force to push apart the particles of water so as to form them into vapor, and when there is heat in the water it constitutes such force.

The moisture at the surface of the animal body is always evaporating, with a tendency to carry off more or less of the heat of the body—or stated more precisely, the heat at the surface of the body, whether in the water or the contiguous tissues or the surrounding air, is constantly evaporating the water, and taking itself off in the vapor. The drying and cooling process at the surface makes room for more hot and moist particles from the inside, and the sweat glands become so many canals of hot water running to the surface and emptying into the air. This moisture must be extracted from the food and carried to the sweat glands by the blood. The animal imbibes large quantities of water to meet the extra demand. While in the case of cold the force of the circulation is expended in carrying fuel to keep up the fire, in this case it is expended in carrying water to put it out. The result is a perversion of work and an underfeeding and exhaustion of the animal tissues, followed by drowsiness and torpor.

The limits of vital activities, so far as temperature is concerned, are fixed, and not very far apart, by the mechanical (or chemical) constitution of the elements that share in these activities. Within these limits,

however, habit and use have produced a wonderful variety of adaptations. The process of acclimation sometimes requires several generations, and in reality the anatomical differentiation must be considerable in many cases in which it is not externally apparent. In Germany the Amphibians come out of their winter sleep when the temperature gets up to freezing point, but in Cuba, where they have become habituated to a normal temperature much higher, they cannot keep awake at a temperature of 7° C. and some of them go to sleep at 24° C. In the Philippine Islands snakes succumb to 16° to 18° C. or 61° to 64° F.

Bayard Taylor, after spending a winter in Lapland, found the temperature of freezing point oppressively warm. It is said that animals in the Arctic Ocean will die if exposed to a temperature of 30° C. (86° F.) in the rays of the sun. The change of color which takes place in some animals on the approach of cold weather, appears to be another effect connected with the same causes that produce drowsiness. Brown weasels and some gray rabbits turn white on the approach of winter. It is easy to see that this is an advantage in the snowy regions of the temperate zones, in making the animals less conspicuous, and must therefore be a cause of selection. But the cause of the modification appears to be the same underfeeding which is due to cold and which, instead of being shared by the various tissues and producing sleep, is concentrated chiefly on the skin, cutting down its function of secreting and conserving the coloring matters. The white color is the best reflector of luminous heat rays, so that an animal having a white coat will get less heat from the sun, which is probably a disadvantage in a cold climate; while the white coat will radiate his own obscure heat as readily as a colored one. The tropical black probably arises also from defective color function at the other extreme, because black being a bad reflector of luminous heat, it must be regarded as an unfavorable color in a hot, sunny climate.

In one of these extremes it would appear that the tone of the system was unequal to the task of secreting the proper amount of coloring matter, in the other it was unable to get rid of a superabundance of it. Albinos present an example of the defect. They are said to be common among the black races. The bleaching of the hair in age is another example of the letting down of the function, by degrees. In the bleaching which sometimes follows excessive fright, it is dropped suddenly.

An anomaly or freak, which at first occurs as an accident of an organism, if repeated often enough through the persistence of the cause, will become habitual to that organism; and if afterward the original cause that brought it about shall disappear the habit of the organism may still be perpetuated. Sooner or later, however, these habits will disappear, and the anatomical peculiarity which may have been caused

by them will remain as a rudiment. The causes that brought about the color of the skin in very many individuals, if not nations, certainly do not now exist, and the diversity of colors is, in many cases, kept up by the ancient inherited habit.

Quick results in the color of the products of the epidermis are sometimes obtained in the lower animals by change of food. Thus, it is stated by Semper, that the green of the feathers of the Brazilian Parrot can be changed to yellow or red by feeding the bird on the fat of certain fishes; that the Bullfinch turns black when fed on hemp seed; and that the colors of certain Canary birds, of the Indian bird Lori Rajah, and of butterflies, depend on the quality of their food. There is nothing at all incredible in this statement, in view of what we know of the effects of food in other things—both directly and indirectly. It is well known how bees develop their queen from the larva of what would otherwise become a sterile female, by food of a peculiar sort.

"The larvæ of a moth—*Acronycta*—entirely lose the habit of spinning a cocoon before assuming the pupa state, when their food is insufficient, and both the pupa and moths are then smaller." Semper, in experimenting with the Mexican Axolotl, an amphibian which is now known to be the larval or incomplete stage of the Amblystoma, but which can and constantly does reproduce in its larval state, kept eight of them for two years without breeding by stinting them in their food. He kept them in a small aquarium destitute of plants and sand. Afterward he removed them to a large aquarium supplied with plants and sand, pebbles, &c., and in the course of fifty hours they deposited about 1,000 eggs. This is another illustration of the fact that reproduction is preceded by a check in general development, and is parallel to the statement in regard to the frog, &c., it answering the same end, whether the pause in development is caused by defective temperature or inadequate food.

CHAPTER XX.

VARIOUS MODIFYING AGENCIES.

In the foregoing, many examples are given to show that changes in animal organisms are caused by changes in their mode of life. Changes in the mode of life, or *habit*, never can occur as long as the conditions remain the same. The same stimulations must invariably produce the same reactions. This is axiomatic in theory, and receives a myriad illustrations every day. But if the stimulation changes it will beget change in the reaction.

Some further illustration of the effects of altered stimuli on organisms

will be found in the action of *water* with respect to its *saltness* or *freshness.* There are many animals that inhabit salt water only, many that live in fresh water only, while still others are so constituted that they can swim from one into the other with impunity. There are many that inhabit the salt water and would die if transferred to fresh water, that nevertheless have relatives not easily distinguishable from themselves, that live in fresh water and would die in salt water.

The amount of salt in sea-water is from 3½ to 4 per cent. Its effect on animals is due probably to their different facilities of endosmose, or the passage of fluid through the skin. A Crocodile is not affected by a change as its tissues are protected from the absorption of salt by its impervious hide. The Medusa, which is a very soft gelatinous animal, whose tissues are thoroughly impregnated by and differentiated to salt, will die almost instantaneously in fresh water. Experiments with frogs, in which their head and mouth were kept out of the water and their skin only allowed to come in contact with it, showed that they would absorb, by endosmose, enough salt to kill in two and a half hours in a medium holding 5 per cent. of salt; in three hours in water holding 3½ per cent.; in seven hours in 2 per cent., and in twenty-four hours in 1½ per cent., while they could endure with impunity water holding only one per cent. From this it is evident that while any amount of salt is injurious to a frog, and 2 per cent. would kill him, yet the injury of one per cent. would not be vital, and consequently he could become habituated to it, and when he did, that amount of salt in the water would suit him better than none, and two per cent. would suit *as well* as none. If he be allowed time, therefore, to become habituated to each step before being compelled to take another, he could, no doubt, be made to flourish in sea-water.

The injurious effects of a transfer from fresh to sea water, or vice versa, are of various kinds. Some animals are killed, some are checked in the deposit of their eggs, and some are checked in their growth. There are numerous cases going to show that animals have transferred themselves by a gradual migration from salt to fresh water. Since 1860 (Semper states) a certain Polyp, the *Cordylophora lacustris*, which formerly was found only in brackish water near the mouths of rivers, has migrated up the Seine as far as Paris, up the Elbe to Hamburg, and also into English and Belgian streams. At Hamburg it made itself troublesome by infesting the city water pipes.

Several fresh water animals, as Bivalve Shell-fish, the Water Louse, &c., have artificially been gradually adapted to salt water till they were made to live and breed in the sea. Of course it must be held that the intimate molecular structure of an animal that has undergone such a change must have also been altered, even when not discoverable, but

there are further examples in which this fact is verified by an accompanying visible change in external morphology.

The fresh water crustacean *Branchipus Stagnalis* is very much like a salt water species, the *Artemia Salina.* But the two are placed by naturalists in different genera. The difference is chiefly in the shape of the antennæ of the male and the number and *form* of the posterior segments of the body, there being nine of these segments in the Branchipus while the Artemia has but eight. There is another salt water species of Artemia, the *Artemia Milhausenii*, which differs considerably from the A. Salina.

The naturalist Schmankewitsch experimented with these, and by raising several generations of the A. Salina in water, the saltness of which was increased gradually from 4° to 25° Beaume's scale, the descendants of the A. Salina became genuine *A. Milhausenii.* At the same time by reversing the process beginning with the *A. Milhausenii* and gradually freshening the water its descendants became A. Salina.

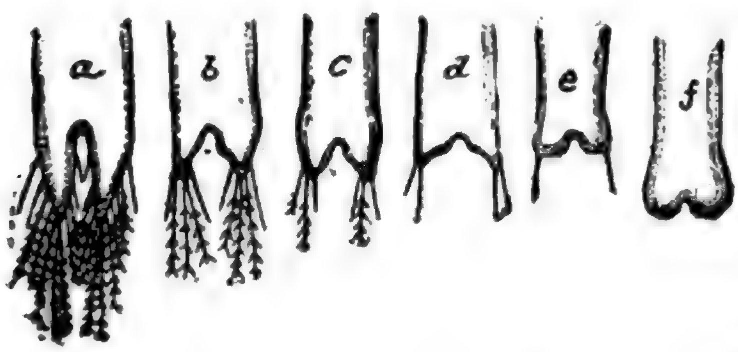

FIG. 76.—*Transformation of the tail of the crustacean Artemia Salina to that of Artemia Milhausenii.*
a.—Tail lobe of *A. Salina.*
b, c, d, e.—Gradual changes as they breed in water of increasing saltness.
f.—Tail lobe of *A. Milhausenii.*
[*From Semper after Schmankewitsch.*]

The two species cannot possibly live together in the same kind of water, but the proof is beyond question that they are related by blood and have been differentiated by the action of salt. Schmankewitsch furnishes figures of the gill and tail lobe, showing the steps taken by the animals in this curious transformation. There are six stages in the tail development, each one inconsiderable, but amounting in the sum to a sufficient difference to justify the specific distinction made.

But the naturalist went still further, and by gradually freshening the saline water in which the *Artemia Salina* flourishes, he caused the descendants of that, in the course of a few generations, to become true fresh water Branchipi.

It would appear, then, that the stimulus of the addition of a little salt to the water surrounding the Branchipus, finds expression in subtracting one joint from his tail. From the foregoing results it is easy to understand why marine and fresh water species can be related while neither could be abruptly transferred to the medium of the other. The *Palemon* is a fresh water Crustacean found often in mountain streams. All of his relatives are marine. In his gill cavities he supports a parasite, one *Bopyrus*, and all the relatives of the parasite are likewise marine, inhab-

iting the gill cavities of marine fish. So the Palemon, in migrating from salt to fresh water, took along his faithful parasite and both were modified to suit their new surroundings. Cowries, a marine univalve mollusk, have migrated up the Niger as far as Timbuctoo. In Mindinao, one of the Phillipine Islands, Semper found oysters in water which at low tide is quite fresh, and never very salty. Likewise the American Manatus or Sea-cow, a marine animal, has gone up some of the South American rivers, and a species of the Dolphin is found 600 miles up the Irawady river, but considerably modified from its relatives in the Indian Ocean. According to Cuvier there is another Dolphin, the Soosoo, living in the Ganges. There are numerous other cases of migrations with such modifications as their new surroundings have imposed—of snakes, worms, fish, and mollusks.

Another curious fact, developed also by Semper, is that the *volume* of water in which animals grow has an effect, within certain limits, on their size. The pond snail—*Lymnea stagnalis*—was experimented upon. As fast as the animals were hatched from a certain mass of ova, they were separated into two lots, one of which was divided equally and placed in unequal bodies of water, and the other divided unequally and placed in equal bodies of water. After a period of sixty-five days it was ascertained that those animals that had an average of 100 cubic centimetres of water, had attained a length of six millimetres, those having 250 parts of water were nine mm., those having 600 were 12 mm. and those having 2,000 were 18 mm. By working out these lengths into cubical bulks, I find that the relative sizes of the animals were as 1, $3\frac{1}{3}$, 8 and 27. These numbers divided into the quantity of water each had, shows that while 100 cu. centimetres gave its bulk to the first one, 74 or 75 cu. centimetres was sufficient to give the same bulk to the larger ones. In 5,000 cu. centimetres the snail would, in about a year, attain its greatest growth of 24 mm., or 95-100 of an inch. Any more water would make no difference. As the snail breathes air, and abundant food was supplied to all, the result shows that the water must supply in proportion to its bulk between the limits of 100 and 5,000 cu. centimetres, something else besides mere wetness—and a potential something, too. A parallel effect to the above is seen in nature in the fact that Salmon, Trout, and other kinds of fish, are always larger in larger streams, and it is not improbable that the mere volume of water may supply the cause, as in the case of the snail.

When such causes as the saltness or volume of water can effect the anatomy of animals, many changes in the natural history of the past are accounted for. A change in the size of a pond or lake, a diminution in the rainfall, by which a lake may cease to have an outlet—as in the case of the Utah Salt Lake, and the Devil's Lake in Dakota—a cir-

cumstance which would cause the water to become salted, would inevitably change all the animal life involved, or perhaps destroy it entirely —of both of which Geology furnishes many examples.

Mechanical Effect of Water.

When we come to discuss the osseous structure of vertebrates, we shall see how habitual strains develop particular parts. We have an illustration of this in the development of organs in flowing currents. Currents constantly cause involuntary migration in very many aquatic animals, sweeping them into new environments, where they are either destroyed or modified to suit their new environment. This happens particularly to animals without organs. On the other hand, all animals with swimming organs have them developed or adapted to contending against the currents. An organ used for beating against the water will naturally tend to take the form of a fin, since that form combines lightness, strength and flexibility, with a minimum of friction and maximum of surface. Natural selection would inevitably pick out such an organ for swimming. And no matter what shape the organ may be, if it be put to work in the water it begins to assume the character of a fin. There can be no doubt that the first limbs were of the nature of fins, which were modified from folds or ridges of the integument, on the back, belly, tail and sides. From fins the limbs of reptiles and land vertebrates were gradually modified, and whenever any land vertebrate has found it advantageous to again have recourse to the water, his limbs have been modified backward toward the model of the fins. Ducks, Cormorants, &c., use their wings both for flying and swimming. But the Penguin uses his for swimming only, and so they have actually been modified from wings into fins not yet as complete or as shapely as those of fishes but still quite effectual. The feathers have become very like scales (See fig. 74). Crocodiles, Turtles, the Ornithorhynchus, Otter, &c., have webbed feet. The limbs and hind end of the bodies of the marine mammalia, Whales, Seals, Dolphins, Dugongs, &c., have all been modified from the forms of land mammals toward those of fish. That such modification has taken place, is unquestionable, and it is both proof and illustration of the sort of reaction which is provoked in the vertebrate organism by the dynamic agency of water. The limbs of those insects, crustaceans and worms which have become aquatic, are modified and adapted more or less completely for swimming. And all these swimmers are in a constant struggle, in maintaining themselves against currents or in moving themselves in pursuit or retreat, the weaker constantly lost in the struggle and the strong becoming stronger from generation to generation.

A great many marine animals that are sedentary in their habits, have organs for holding on to some rock or other object, so as to keep from

being washed about by currents, as the Crinoids, the Lingula, and other Brachiopod Mollusks, the Tunicates, &c. In many cases it is known that such clinging organs have been modified from organs of active locomotion. This is the case with the Anatifa and the Barnacle, as mentioned further on; the clinging stem of which is modified from the fore limbs, with which it swims while in the nauplius or early infant stage.

Among the curious examples of the morphological adaptation of an organ is that of the evident modification by which the univalve Gasteropod *Navicella* has been developed from the *Neritina.* There is practically no difference between them except in the form of the foot and its cover or operculum. The Neritina when alarmed instantly draws into its shell, pulling its foot after it. And the operculum, like a hoof, closes up the mouth of the shell snug and tight. But with such a habit he can live only in comparatively still water, or he would be carried off or dashed to pieces when he loosened his foot-hold. The Navicella, on the contrary, when alarmed does not let go, but hugs down upon the object he happens to be on all the harder, covering his foot under him with his shell over his back. He has come to do this by a habit of living in a current where it was unsafe to let go, and those of his kindred who did were probably selected out of existence. But by thus keeping this foot always extended and the operculum always open, the foot has grown to such a form that it can no longer pull the operculum shut, and if it could, the cover has grown so distorted by disuse that it would no longer fit or nearly cover the opening, so it is, in fact, reduced to a useless rudiment.

Dessication.

Among the curious habits to which animals may become differentiated, is that of dessication. This dessication takes place in the egg and among invertebrates only. The eggs of the following animals may be dried and kept, some of them for years, and then moistened and hatched—a great number of infusoria, sponges and worms; and of Crustaceans, the Apus, Branchipus, Brine Shrimps (Artemia), Water-flea (Cypris), Branched-horn Water-flea (Daphnia), Cypridina, Limnadia, Estheria and many Copepods (Cyclops). Some of these eggs are very small, so that when dry they can be carried about by the wind. They have attained the ability to stand this drouth by living in places subject to being dried up in the summer. The mud containing them can be kept for years, and the eggs then hatched by moisture at a proper temperature. But the most curious feature connected with it is that the habit of dessication is so fixed as a part of their development, that some of them, for example those of the Apus, never will hatch out till they have been dried, and lain for a certain time in the dry mud.

Reptiles do not incubate their eggs. In the snakes the young are

partly formed when the eggs are laid; and it is possible to compel a snake to become viviparous artificially. This has been done by M. Geoffroy by depriving a common snake of water. In this case the eggs could not be laid by the snake but were retained until they were hatched internally. The development of the lizzard, Axolotl, into its adult and final form, called the Amblystoma, is effected by depriving the former of water.

There are over twenty species of Amblystomas in America, some of which in their development stop at the Axolotl stage, while others go on to become Amblystomas. The difference between the two is much the same as between their Amphibian relations, the tadpole and the frog. Like the tadpole the Axolotl breathes in the water by means of gills, and like it acquires lungs, but unlike it does not always drop the gills and pass into an air-breather exclusively. As an Axolotl, with both gills and lungs, it may live, reproduce Axolotls and die without further development. But according to experiments with them in several places in Europe, when the Axolotls are about six months old their lungs are so far developed that they can almost live without using their gills at all. If they are then placed where they can choose between land and water, they will spend part of the time on land, and by gradually diminishing the water till it is all gone, their gills will become dessicated and shrivel, and the whole of the respiration then becomes aerial. In eight days after finally leaving the water, their gill slits are entirely obliterated, the skin is moulted, the dorsal crest or fin is shrivelled up, the tail becomes more rounded, and the adult form of the Amblystoma is reached, the whole process taking place within nine months of birth. Undoubtedly this is precisely the process by which this curious development is brought about in a state of nature. These animals inhabit ponds that, in the drouthy districts of Mexico and Western United States, are apt to dry up in summer, and they have, by hereditary habit, gradually come to adopt aerial breathing and to rely upon it exclusively when necessary. But we may conclude that the habit is of comparatively recent origin, because the gills require to be mechanically shrivelled by the dry air, and if the animal has plenty of water, he may remain in it and not shed his gills at all. In the case of the Frog, the habit has become a necessary link in the chain of its development, and the gills are shed at a certain stage regardless of moisture.

But there is another case arising from the same cause that has gone further.

The black Salamander of the Alps, is exclusively a lung breather, and does not inhabit the water at all. Nevertheless, the embryos, which are retained within the body of the female to be hatched and developed, have complete gills which they shed before they are born. If these

young Salamanders are taken out of the mother at a certain time and placed in the water, they will breathe by their gills, their development will continue and they will finally become land Salamanders. Their development in the matrix of the female is much more rapid than when they are thus taken out, a fact recalling the compression, within this short space of time, of the adult lives of the ancestral forms, which takes place more or less distinctly in all embryonic development. (Wilson's Evolution, 244.)

The history of this Salamander is, no doubt, in the same direction as that of the Axolotl, and indicates that its modification has been caused by an increasing habit of living without the water. It has either climbed the mountains, leaving the water behind it, or the mountains, in being elevated in ancient times, carried it upward and gradually the water disappeared, and the amphibian was modified to suit. The fact that the embryonic gills of this animal are real and capable of performing functions which, nevertheless, in a state of nature they are never called upon to perform, is exceedingly curious and instructive. It points conclusively to a time in the past, not very remote, relatively, in which the young Salamander was born before he parted with his gills, and habitually used them in aquatic respiration. And it illustrates the point so much insisted upon by evolution, that the development of every individual involves the imitation of every successive stage in his ancestral line, all the stages but the present being compressed into the short period of his antenatal life.

The fact is, that every vital process is a matter of habit. Every form is an outgrowth of its predecessor, and, consequently, cannot appear till its predecessor has appeared. It is the endless repetition of this succession of forms that has given it the facility that constitutes habit. The older stages have been repeated oftener than the later ones, consequently they are passed over more rapidly. Every generation compresses into the last moments of its prenatal life the essence of the modifications that took place in the preceding generation. The course of this prenatal development is under the influence of the environment, but that influence has a much less modifying effect upon the earlier than upon the later stages, because the earlier are more firmly fixed in the line of habit. It is on this account that the larval stages of the invertebrates and lower vertebrates, which answer to the later prenatal stages of the higher vertebrates, are, to so great an extent, subject to the influences of the environment heat and cold, moisture and dessication, quality and quantity of food, &c.

The fact that such larval forms as the Axolotl, are able to reproduce, shows how exactly the later of its ancestors, in their adult form, are imitated, in its now larval form, so exactly that all the essential vital functions of the ancient adult are copied by this infant.

Food.

As examples of direct anatomical modification by food-habit, may be mentioned the conversion of the gizzard or hard stomach of birds into a soft stomach, and vice versa. The gizzard of the Pigeon is changed to a soft stomach by a continuous diet of flesh; while the soft stomach of a Sea-gull has been changed to a tough, gristly gizzard, by feeding on grain for a year. The Herring-gull in winter lives on fish, and has then a soft stomach, but in summer it lives on grain and its stomach changes to a gizzard. It has also been observed in a Raven and a species of Owl, that the internal coats of the stomach change twice a year to suit their food. The habits of some animals have been fixed for so many generations, and their anatomical structure has become so conformed to the habits, that to change radically from their accustomed food would be death to them. But food is food, and, if time enough be given, any change can be wrought. The lion could, in the course of generations, be made to eat straw like an ox, and the horse to relish fried oysters. As it now is, the various animals are habituated to special lines of diet, which, in certain cases, are very narrow. Some live on a particular article of animal food or vegetable food, others on a general class of animal or vegetable food, and still others on a mixed diet.

The food has acted upon the animal structure, that it has habitually nourished, directly, in forming and fixing anatomical peculiarities, and at the same time establishing the mental characteristics corresponding to them. The character of the food first affects the stomach, an example of which is given in the case of the modification made in birds by changing from flesh to grain. The stomachs of animals in general differ from each other and correspond in form with the demands of the digestive function, whatever that may be.

The herbiverous animals, as a rule, have larger stomachs and longer intestines than the carnivorous, because the quantity of vegetable food required is much greater, as a rule, than that of animal food to produce the same amount of tissue nourishment or heat. The ruminants, or cud-chewers, eat enormous quantities of bulky grass, and have stomach capacity to correspond. In fact, they have four stomachs; viz., paunch, honeycomb, manyplies and rennet. The food goes in part into the honeycomb, but mostly into the paunch, which, in the adult animal, is an immense bag. It is relatively small in the young, and is only developed by the bulk of food it receives. From the paunch the food goes into the honeycomb or reticulum, and passes back and forth from one to the other, and between them is macerated into a semi-fluid mass, mixed with saliva. It is carried up from there in boluses back to the mouth to be further chewed and salivated. On its return, it flows over the more solid, less fluid, unchewed portions into the manyplies, and

thence into the fourth stomach where it is mixed with the gastric juice. The reticulum is lined with ridges which cross each other in such a way as to form the honeycomb-shaped sections. The manyplies has a lining of plates, like the leaves of a book, which serve to strain the food and keep back the coarser, unchewed portions for further reduction.

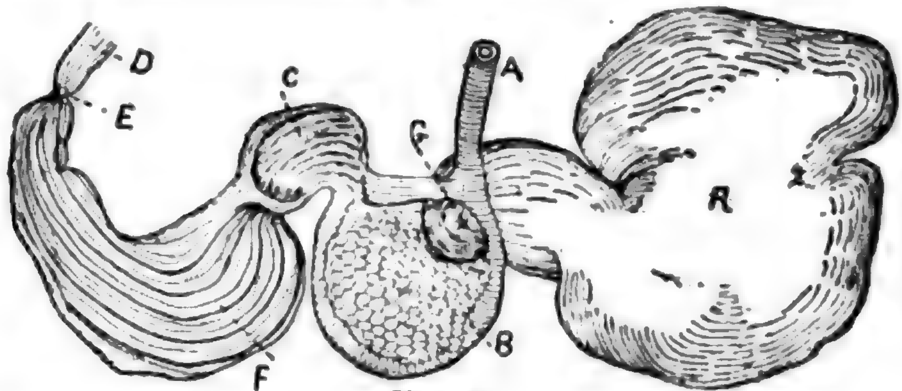

FIG. 77.

FIG. 77.—*Stomach of a sheep.* (*Huxley, Vertebrate Anatomy.*)
A.—Esophagus (gullet).
B.—Reticulum (or Honeycomb).
C.—Psalterium (or Manyplies).
D.—Duodenum (small intestine).
E.—Pylorus (or gateway).
F.—Abomasum (or Rennet stomach).
G.—Opening from the Rumen to the Reticulum.
R.—Rumen (or Paunch.)

The intestine and the cœcum of ruminants are both long. (For cœcum see fig. 67.) The rodents, or gnawing animals, likewise feed on bulky food, often wood and the bark of trees. Their intestines are very long, and their cœcum also extremely large.

The edentates, that feed chiefly on leaves of trees, as the Sloth (Bradypus), have stomachs of enormous size, and divided into four compartments, while their relatives, the Armadillos and Ant-eaters, have small, simple stomachs. The Bats, whose food is chiefly animal, have small intestines without cœcum, while their relative, the Galeopithecus, that lives on leaves and fruit, has a large cœcum. The Insectivora, living on concentrated food, are without a cœcum. The small, but ferocious and blood-thirsty Weasels, Martens, Skunks, Otters, &c., are also without a cœcum. The second division of the Carnivores, including the Dog, and Cat tribes, Fox, Lion, Tiger, Hyena, &c., have small cœcum. The Pachydermata, which are all vegetable eaters, have large stomachs, with long intestines and immense cœcums. They include the Horse, Elephant, Rhinoceros, Hippopotamus, Tapir, &c. In the case of the Hippopotamus the stomach is divided into several sacs. The cœcums of the Elephant and Horse are enormous.

The herbivorous cetacea have a stomach divided into four sacs, and their cœcum is large. They are the Manatus, Dugong, &c. The Dolphin tribes of the cetacea are more carnivorous, and do not possess a cœcum, although they and the rest of the ordinary whale tribes have complicated stomachs divided into several sacs, and they have several spleens. It thus appears to be a common rule that a cœcum goes with a vegetarian diet, or at least a bulky vegetarian diet. While those animals which are carnivorous, or at least whose diet is small in bulk, have

none. The Bears appear to be an exception, for although they are placed among the carnaria, in Cuvier's classification, their dentition is almost frugivorous, and the preferences of most of the species are for wild fruits with honey, &c. When these fail they will catch fish or small mammals, such as pigs. Even the Polar Bear, which habitually lives on fish and seals, can be made to subsist on a vegetable diet. Yet these plantigrade animals, in common with the insectivorous plantigrades (Hedgehogs, Shrews, Tenrecs, &c.) and the semi-plantigrade Weasels and Martens, possess no cæcum.

These animals are perhaps derived from a carnivorous ancestry, and have not as yet made a sufficiently radical change in their diet, or have not been subject to the change long enough to work much change in their alimentary system, or the change may have taken the form of an increased length of intestine. Cuvier remarks that the length of the intestine of the domestic cat is much greater than that of the wild cat, obviously owing to the less carnivorous and concentrated nature of its diet.

The subdivision of the stomach into several sacs appears to be supplementary to an imperfect mastication, and is supplied to animals that bolt their food without chewing it, as in the case of the ruminants, and also the whale tribes who swallow their food "in oceans" and never chew it.

The indirect effect of food upon the animal, besides its influence on the nervous system through the peculiarities of its various chemical reactions, whereby the mentality, temperament, &c., are largely formed, consists in developing the habits necessary for its procurement. If the food has a habit of growing at the top of a tree, the animal must adopt the habit of climbing after it. If the food grows at the surface of the ground, the head of the animal must be bent down to reach it. If it is under ground he must learn to dig for it, if under water, to dive for it. All the ten thousand acts required from one or another to procure their food, tend to modify, to a greater or less extent, the organs that are brought into requisition for the purpose; constantly improving them by the practice that makes perfect, while heredity clinches every modification that survives the test of utility and the competition of the struggle for life.

Head and Tail.

Among the first and most obvious differentiations in the animal body, as already observed, is that by which the inside is distinguished from the outside. Next and equally obvious and automatic is that subdivision of the outside by which, in all vertebrate animals at least, a top and bottom become recognized as the dorsal and ventral sides; flanking these two other aspects become the right and left, and the two poles become the fore end and hind end or *head* and *tail.*

It was observed that among the zoophites, or plant animals, as sponges, corals, etc., the animal has but one orifice opening into his bag-like stomach, and this serves both for ingress and egress. In animals of somewhat higher development we find the single external orifice replaced by two; but they are not far apart. It is as if a partition reaching not quite to the bottom of the original cavity had been inserted so as to form a continuous U shaped canal with an opening at each end, one for ingress and one for egress. As an important condition of animal life is to have a steady income of food, whatever organs were developed for its procurement would obviously be located near the entrance. Accordingly we find the parts around the mouth becoming modified into cilia, flagella, tentacles, and finally jaws, &c., and this modification is accompanied by a corresponding development of nervous machinery. All this finally promotes the part about the mouth, and including it, to the position of *head*.

By reference to table V in Chap. VI it is seen that the Gastræa, or sac-like animal, is a common parent of two diverging stocks; viz., radiate animals and bilateral animals. There is a certain degree of bilateralism even in the radiate animals, and whether the rays are of even number, four or six, or of odd number, five, the mechanical requirements of locomotion will invariably tend to make the animal two sided in action, and action, reacting upon the parts engaged, tend to make them over and better adapt them for locomotion. Those animals which remain radiate in structure are usually sedentary in their habits, many of them becoming fixed and stationary for life. True bilateral locomotion begins with the worms. There is almost conclusive evidence that the original worm is simply a co-operating colony of Gastræad or sac animals strung along in a row one behind the other. These pieces are called somites (bodies),

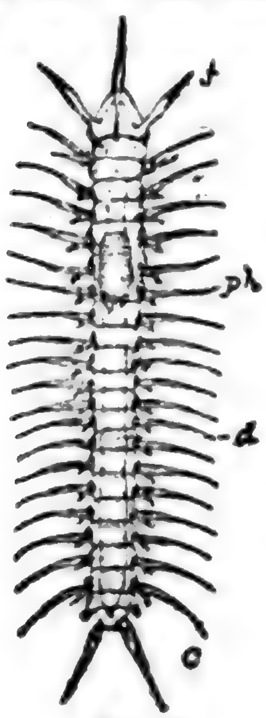

Fig. 78.

Fig. 78. *A Chætopoda worm.* (*The Grubea fusifera.*)
Segmented worm.
ph.—pharynx. *d.*—alimentary canal. *f.*—tentacle.
c.—cirrus. (*Claus after Quatrefages.*)

or sometimes segments, and originally they must have been of equal value from one end to the other. But in the interest of economy differentiations would soon take place. One mouth, one set of tentacles, &c., would answer for all the somites, and so all the others might be dispensed with. In such worms as the Polychæta, Chætopoda, &c., the segments are each provided with a pair of limbs which all work in unison to carry the animal forward. But the two end segments are different from the rest. The one in front containing the principal sense organs, mouth, &c., is called the *peristomium*, or "part around the mouth." In locomotion

it pilots the way. The one at the other end is called "pygidium," which means simply a "little buttock," and might as well be called the *tail.* It possesses sensitive cirri or feelers which project toward the rear and give warning of hostile demonstrations from that direction. The building of a single body out of a consecutive series of sac-like animals, would require a particular pattern that could be fitted together and made to coöperate. Obviously, those having the U-shaped intestine would not do.

The segments of a worm of the simpler sort have an alimentary canal running straight through from end to end, each of the composing segments being perforated at each extremity. In the higher grades, much complication and twisting occurs in this organ, and the somites gradually lose their identity. Various viscera may be constructed in some of the segments which do not extend to the others, though serving all. The exit of the alimentary canal, which should be in the extreme segment, becomes located further forward, and the tail segment becomes specialized for work.

The kind of work it first became fitted to do was locomotive. To an animal living in the water, a tail is a vast acquisition. This is proved by the fact that when the land mammals, with good limbs for getting around on land, and with diminished tails, took to the water and adopted an aquatic life, their limbs became modified backward toward the type of fins, and their tails and hind quarters gradually became powerful propellers. As the worm became modified into the vertebrate type, the segmental limbs became eclipsed by the great progress of the tail as the main propeller. The Amphioxus (Lancelet), the lowest vertebrate now living, has no vestige of bilateral limbs, and those which were afterwards developed in the vertebrate, arose from folds of the skin along the sides, back and belly of the animal, as assistants to the main propeller, the tail.

The tail of the early fish is straight and tapering to a point; but in the bony fishes this tail is greatly improved. Width is added to it by the development of a fin on the underside, which at first gives the tail the appearance of being forked unequally, but as this underpart continues to increase, the tail becomes symmetrical. This is accomplished at the expense of much alteration and unseemly distortion of the rear end of the ancient backbone of the old cartilaginous fishes. But new habits of activity required the alteration, and made it. A superiority of the tail as a propeller made locomotion easier and opened the way for a larger energy to go towards improvement in other directions. The head and tail are complemental of each other, and the differentiation of the tail from the rest of the body at one end means also the differentiation of the head from the other end. As long as the tail remains an ac-

tive organ, it constantly, by its reactions, contributes to the building up of the brain and sense organs; and the reaction of these again stimulates further locomotive development, which finally takes the form of fins. These rather at first serve to give greater steadiness and accuracy to the motion and a better control of the animal by his brain. As long as the animal remains in the water, a good tail is an index of high standing. But on land it is different.

When the fish took to living part of the time on land, his fins came into play as feet; not very good ones at first; but getting better generation after generation.

The tail reaches its culmination as to size, among the reptiles whose lives are spent principally in the water. Those living chiefly on land no longer need the tail as a propeller. The limbs increase in importance and in the completeness of their adaptation to the life followed by their owner, and in the same proportion the tail is on the wane. The epitome of his race history is repeated before our eyes every spring, in the development of the tailless frog through the form of its tailed infancy. The larval frog, swimming in the water by means of its tail, and breathing like a fish through its gills, gradually puts forth limbs and develops lungs, while tail and gills as gradually become suppressed. For a short space he uses gills and lungs, tail and legs; but soon the gills and tail are eliminated, and lungs and legs remain in full force. On land the tail is of no value as a propeller, and sooner or later takes a back seat. On its way to final extermination it makes itself useful to some tribes in a much reduced capacity. To a monkey its function of *holding on* is the exact opposite of that which sends the fish through the water like an arrow. The horse, ox, &c., make a mild use of their much-diminished tails as fly-brushes.

Those enormous reptiles, the Deinosaurs, which inhabited the land in the Jurassic times, must have found their enormous tails a burden, as any useless appendage always is, and, consequently, until their descendants got rid of it they would be hampered in the struggle for existence.

In a much later age we find the great, sloth-like Megatherium using his massive tail as a third hind leg, the three forming a solid tripod, on which he could sit while he reached for the upper branches of a tree. The early birds, which were only modified reptiles, inherited their heavy tails. The ancient bird of Solenhofen, the *Archæopteryx*, had a tail containing twenty vertebræ. The tail of the modern bird, which is a descendant of such forms, is now a mere stump, having generally nine vertebræ, three of which are fused into one—the coccyx. The ancestor of the present *Brachyouran*, or short-tailed crab, was the *Macrouran*, or long-tailed crab. In all mammals, whether it is of any use or not, the tail is, comparatively speaking, a rudiment. In certain breeds of sheep

it is reduced to a mere button hidden in a mass of fat. In the Manx Cat, in the higher Apes, and in Man, it is a subcutaneous rudiment which never penetrates the skin, except in some rare cases of reversion or arrested development.

CHAPTER XXI.

BILATERALISM.

Bilateralism, or the possession of two complementary sides, which has reached a considerable degree of perfection among the vertebrates, is a subject of development as much as the differentiation of an inside from an outside. Many of the lowest invertebrates are not bilateral, as Hydra-polyps, Bryozoa, Medusæ, Star animals, Echinoderms, &c. Locomotion in these animals, where there is any, is by means of limbs radiating at equal angles from a common center—the mouth or stomach. Most mollusks are, in part, bilateral, as are all the articulated animals, including insects, worms and vertebrates. The development of complemental sides seems a most obvious mechanical necessity and result, when we consider the nature of locomotion. The muscles of the tail of a fish, for example, must be able to flap the tail as much to the left side as to the right, or else what motion the fish would have would be extremely one-sided and impracticable. All locomotion depends upon the exertion of muscles, that is, their alternate contraction and relaxation as stimulation reaches them or ceases to do so. Such stimulus causing the contraction of the muscle fibres on one side of a worm, for example, would cause that side to move, but it could not go far without the other side and the motion would tend to be in a circle and without purpose, till the other side should receive like stimulus. Then a definite locomotive progression becomes possible. To this necessarily alternate reaction of the right and left sides against the stimulus of the contact of the outside environment (which to the earliest organism was water) is, without doubt, to be attributed first, the differentiation from the general sensibility of the organism, the sense of touch or contact; followed by the further differentiation of the other sense organs from it; and contemporaneously the differentiation from the general contractility of the organism, of a special and superior contractility to be thenceforward located in the muscles of the sides. Under the special stimulus thus directed to localized points, the muscle fibre has received its peculiar properties and at the same time in connection with the muscle the nerve fibres have been specialized by use for more perfectly conveying the stimulation from a part in direct contact with the stimulus to a remote part not in such direct contact. Any peculiarity in the application of

the stimulus causing a peculiarity in the reaction of the muscle, tends obviously to the setting apart or differentiation of certain muscle fibres to certain forms of movement, and finally to new anatomical structure, and hence limbs or locomotive organs on each side. The development of the organs of the vertebrates being thus traceable to the bilateral action of the original stimulus to motion and sensation, it is not strange that the organs exist in pairs to so large an extent, especially those of locomotion and sense. The two limbs on each side, the eyes and ears in pairs, the double hemispheres of the brain, these are to be expected. But the mouth and intestine is single from the highest to the lowest, and that any of the products of either should be double is remarkable, but may be explainable as the effects of later reaction of the outside of the body upon the inside. The double parts, of internal origin, are the kidneys, the ovaries and testes, and, later, the liver, lungs, double-uterus, double male organ, and double nostril. The history of the development of bilateralism is exceedingly curious, and its results to our race are extremely important, as will appear.

Some organs, after occurring as double in the lower animals, become consolidated, or tend that way, in the higher. On the other hand, some, which in some of the inferior forms are single, finally become double in the superior. The cerebrum, which in man is the principal

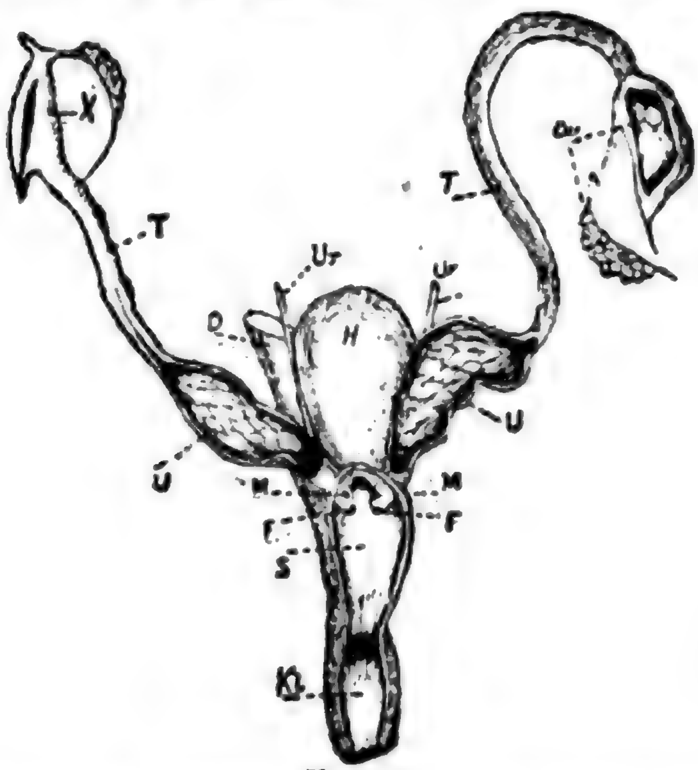

FIG. 79.

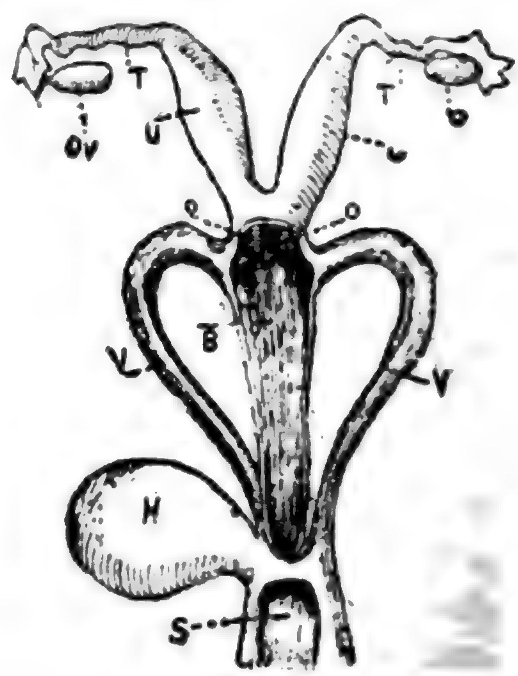

FIG. 80.

FIG. 79.—Female generative organs of *Ornithorhynchus.*
OV.—Ovary.
X.—Non-functional right ovary.
T.—Oviduct.
U.—Uterus—double.
M.—Mouth of uterus.
S.—Urogenital sinus—or receptacle.
Kl.—Cloaca.
D.—Intestine running down behind S and opening into the cloaca.
Ur.—Ureter.
F.—Opening of ureter.
H.—Urinary bladder. (*Owen.*)

FIG. 80.—Female organs of a Kangaroo—Halmaturus.
Ov.—Ovary.
U U.—Uterus.
B.—Cœcum of vagina a pouch closed below.
T.—Oviduct.
o o.—Mouth of uterus.
H.—Urinary bladder—opening into S.
S.—Urogenital sinus. (*Gegenbauer.*)

part of the brain, is double, right and left, in all the higher vertebrates, while it is undivided in the lowest. The lungs start from the air bladder of fishes, which is at first a single sac, but later is found double. In the Ceratodus and Lepidosiren these bladders become true double lungs. In the Cyclostomi the nose is a single tube, but in the early fishes (Selachians) this is divided into two, remaining such in the higher animals. In the Cyclostomi the sexual glands, ovaries and testes, are paired, but no supplemental organs are required as the impregnation takes place after the eggs are laid or thrown off.

The same is true of the Amphibians. But in the Monotremes, Ornithorhynchus, &c., with which the impregnation is internal, additional organs became essential, and these were developed in pairs. *Each* ovary of the female was supplemented by a uterus, and *each* testis of the male by a penis. These double organs persist, more or less completely, in the most of the genera of the Marsupials, as the Opossum, Wombat, Kangaroo, &c. From the Kangaroos up, these double organs have become partly united to form single ones. In the Lemurs the two uteri are united at their lower ends, leaving the upper ends still free. In the Apes and Man they are consolidated into one, and the only suggestion of their duplex nature remaining to these races, is in the two fallopian tubes entering the upper opposite corners; the representatives of the upper ends of the ancient Müllerian ducts; the united uteri with their outlet representing the lower ends of those ducts. But the organs all still retain marks of their duplex origin.

In some of the ganoid fishes—as the Amia calva—the urinary bladder is a double organ, one bladder being developed in connection with each kidney by the dilation of the ureter. In the Selachian fishes the ureters, or ducts leading from the kidneys, are dilated, but not to the extent of bladders, while in the Cyclostomi—Lampreys and Myxine—there are simply the two ureters opening behind the rectum. On the other hand, in the bony fishes (Teleosteans) the two urinary bladders of the ganoids are consolidated into one bladder which receives the two ureters, and which still opens behind the rectum. In all the higher vertebrata the single urinary bladder prevails, but the natural original position of the external openings is reversed with reference to each other, the urogenital opening being in front instead of behind the anal. In this case, then, it would seem that the organs beginning as duplex have tended to a consolidation into one. And the same may be said of the reproductive organs, some of which have thus become consolidated from two into one, while others still remain in duplicate. Some further examples may be mentioned. In many genera of the Rodents, as the Rabbits, for example, the uterus of the female is still completely two, each of which opens separately into the vagina. The male Rabbits have *two*

scrotal sacs. The males of several genera of Reptiles have a forked or double organ of generation—corresponding with the double ovary and two oviducts of the female. In some cases, these two male organs are so far separated from each other that one appears on each side of the cloaca—contained in a sac. Some reptiles of the lizzard kind possess double reproductive organs. The uteri of seals are partly consolidated, but still divided by a partition or septum.

In many animals the tongue is double. This is the case with snakes in general, and some lizzards. The tongue of the seal is also split at its extremity. The upper lip of the rabbit is double, being cleft in the middle, and so is that of the camel. The human deformity called "hare-lip" is such a cleft in the middle of the upper lip, and is often accompanied by "wolf's-jaw," which is a corresponding cleft or fissure in upper jaw-bone and of the palate. This deformity is caused in embryonic development by the failure of the tube of the body to close at this particular part of the median line of closure along the belly side of the body, and is, in a certain sense, a reversion.

Mention has heretofore been made of the intermaxillary bone, which occupies the front center of the upper jaw in apes and in the human embryo. In most of the vertebrates, except the monkey and ape tribes, there are two bones instead of one. They are called the premaxillaries, and are usually joined to each other in front by a median suture, and are joined at the sides by sutures to the maxillaries. This arrangement is the rule throughout the vertebrate tribes—fishes, amphibians, birds, and mammals. There are some exceptions, however, among the reptiles, the two bones being soldered together in some of the snakes and turtles. In some of the bats they are reduced to rudiments in size. But their transition development is most remarkable in the monkey and ape tribes. These animals are born with the two bones. But at some period of their lives the suture between the bones disappears and they become one. In the Cebus (Platyrhine Monkey of high organization) this happens in early life. Among the Baboons and Mandrils (Cynomorpha) the median suture does not disappear till late, occasionally not at all. In the Chimpanzee it disappears when the milk teeth fall out, but in the other man-like apes, not till after the second dentition is accomplished. (Huxley, Vertebrate Anatomy.)

Thus, most of the higher monkeys and all the man-like apes, possess, in adult life, the single intermaxillary bone. As before mentioned, it is developed in the human embryo, but about the time of birth, or soon after, it is absorbed, and the two sutures, which connect it on each side with the maxillaries, are gradually brought together till they become one—the bone between them quite disappearing. The double gills of worms and fishes seem to be the result of direct correlation of respira-

tory organs with the bilateral activities, and must have been double from the start. With the lungs, however, the case is different. The embryological development of the vertebrate lung is from a single air sac, which divides into two, each of which becomes a lung. Without doubt this was the order of the tribe development of that organ. The original of that single air sac is illustrated by the single air bladder of the bony fishes, while the original of the double sac stage has an illustration in the double air bladders of the ganoid fishes, as the Polypterus. The modification of such air sacs into lungs, and the change from breathing the air in the water to breathing the air directly from the atmosphere are much less violent than one would naturally suppose, as we shall see further on. Among other double organs that may be named, are the thymus and thyroid glands, which have been explained in Chap. V. These are organs concerned in the nutrition of the lower races and the young of higher races, including Man, but which become functionless in the adult Man. The two lobes of the thyroid are joined by a narrowing called the isthmus. The tear glands are paired to correspond with the eyes. The salivary glands are in pairs, three or four on each side of the mouth and jaws. The milk glands are in pairs, usually one on each side, but not unfrequently two or three on a side.

The foregoing examples appear to point to the following generalization: that, as a rule, organs developed directly from the outer tube of the body are, from the first, in duplicate, while those developed from the inner tube alone are at first single. The subsequent modification of single into double organs is due to the more or less independent action of the two sides—each of which establishes relations with a definite half of the single organ, the neutral or inactive tract, between which two halves will first become fixed membranous tissue crystallizing into a septum, and finally a double one, making a permanent division of the two.

The subsequent modification by which two primary organs tend to become consolidated into one may arise from more than one cause. First, where the bilateral action is entirely coöperative and not antagonistical, or in cases where the bilateral functions have ceased, as, for example, in the urinary bladder, which, starting as mere dilations of the two ureters, becomes single by the absorption of the walls between the two.

The function of the bladders, as mere receptacles of the waste, is chiefly a passive function, and economy of room and material, both of which are important instruments of *selection*, will tend, in the course of time, to the elimination of the useless wall and the establishment of the economical, spherical or ovoid shape. The same considerations apply to the development of the single from the double uterus.

A second cause of the reduction of duplicate organs from two to one

arises from the sufficiency of one to do the work and the consequent uselessness of the other. This happens in cases where after periods of activity in which high development is reached, a tribe is forced into inactivity. As a prosperous citizen with twelve children builds a house with fifteen rooms. But when the children are married and gone he and his old dame have use for only three. As seen under the subject of rudimentary organs, the vertebrate body is full of these supernumerary and useless, because unused, parts. Other examples will be given presently. The external tube of the vertebrate body therefore is like the union of two individuals, necessary to each other, yet antagonistical and in severe competition and, like two animals, both dependent on the common vegetative internal tube for nourishment.

It is to be expected that the two sides of this bilateral body should be so joined by nerve connections as that each side being influenced by the action of the other side, the two should act in some degree of harmony or correspondence. Accordingly we find that each segment in worms and the vertebral segments in the vertebrates are supplied with nerves, so that the limbs and organs on one side are always automatically co-ordinated with those on the other, and this co-ordination is further carried from end to end by the spinal cord. The spinal cord originating from the two-sided body is itself duplex, and what may be called its extensions and additions, constituting the brain; viz., the medulla oblongata, the cerebellum and the optic lobes, the optic thalami, the corpora striata and the cerebrum, are all likewise double.

Under the universal law that habit and use increase and strengthen a part or organ, while disuse has the contrary effect, to diminish and abort it, when either side possesses activities not shared or balanced by activities of the other side, the two will become unequally developed and there will be, to a certain extent, a *Want of Symmetry* between them. Our habit of using the right hand more than the left has been followed by its greater development in size and dexterity, and by sympathy the greater size and dexterity of the right leg and foot. And this difference in the bilateral activities of the exterior, react upon the internal anatomy, causing asymmetry in bilateral organs there. Thus the two lungs, which are very directly connected with and essential to external activity, differ materially from each other, the right lung being the largest and divided into three lobes, the left smaller and divided into two.

The right lobe of the liver is also much larger than the left. The brain also is very directly involved in external activities, the cerebral hemispheres being devoted to the correlation of the conscious and intelligent movements. In consequence of the *crossing of the nerves* in the medulla oblongata, the left hemisphere becomes the organ of the right side of the body and the right hemisphere that of the left side. Ac-

cordingly, in all ***right handed*** persons the left hemisphere of the brain is the largest, weighing, on an average, one-eighth of an ounce the most, and very often it presides over the faculty of speech, becoming spokesman for both sides, to the exclusion of the right lobe. The two sides of the several segments of the brain are connected with each other by cross fibers called commissures, and, ordinarily, there is more or less coöperation and correlation between the opposite sides of the brain. But the two sides may and do differ in activity and function, as the two hands differ. The actions of the individual may be governed by the strong side exclusively, or by the two alternately. One side may be authority in some departments, the other in other departments, so that in case of disease to one side the individual may be all right on some subjects and quite insane on others. The eyes also often differ from each other in size and in focal adjustment.

Notwithstanding the mutual dependence of the two active sides of the vertebrate body, there is, at the same time, a certain degree of independence. In general, wherever the organs are double the animal functions can be performed and life sustained for a time with one. Either of the external senses may be active with only one eye or ear or nostril, respiration may go on with a single lung or even less, reproduction with a single ovary and testis, and mental action with a single cerebral hemisphere.

One whole side of the body may be paralyzed, including one-half the brain, without the total destruction of any function.

The curious human habit of preferring the right hand to the left and its consequences are paralleled by similar circumstances among other vertebrates. A remarkable example is the *Flat Fish family.* They have a habit of swimming near the bottom and on one side instead of the belly. As this position brings one eye on the underside looking toward the bottom, it is useless, and the fish from the habit of twisting the head and neck to bring this eye into a useful position on top, has after many generations of effort, assisted by the hereditary transmission of each accumulation of deformity, succeeded in bringing his optics around almost the quarter of a circle. To do this the bones of the cranium and face are twisted over and the median line, instead of being straight as in most fishes, is distorted and crooked. This want of symmetry is often shared by the backbone and limbs, one fin being larger than its mate.

The Monochirus, a member of this family resembling the Sole, has only one small pectoral fin on the same side with the eyes—which is the right side in this genus—the opposite fin being aborted. Some of the genera of the Flat fishes usually lie on the right, others on the left side, and the eyes are on the top side, whichever that is.

In the Soles the eyes are on the right side, the mouth is twisted

toward the left, with teeth opposite the eyes only. The flat fishes are whitish on the under side and dark-colored on the upper side. The upper side also possesses the "Chromatic function," or the power to change color, which the under side does not. Sometimes, however, an individual is colored alike on both sides and is called a Double. The dark side is doubled oftener than the light side.

Occasionally an individual is "reversed," that is, lies and swims and has his eyes, &c., on the side opposite the one his species usually affect.

The embryo flat fish is straight and symmetrical, with eyes in the normal place, but the young one soon begins to assume the sequences of distorted forms that the habits of his ancestors have bequeathed to his race and ends by being as crooked as the rest. This embryonic development is indicative of the race development and proves the flat fishes to be derived from a symmetrical ancestry and modified subsequently into crookedness.

Thus the flat fish is a good example of the effects of an unequal stimulus; that is, the stimulus on one side differing from that on the other, as, with the bottom of the ocean on one side and the upper world on the other, it obviously does.

The occasional "doubles" and "reversions" illustrate the fact noticed elsewhere that the latest variations from a former type are themselves liable to vary.

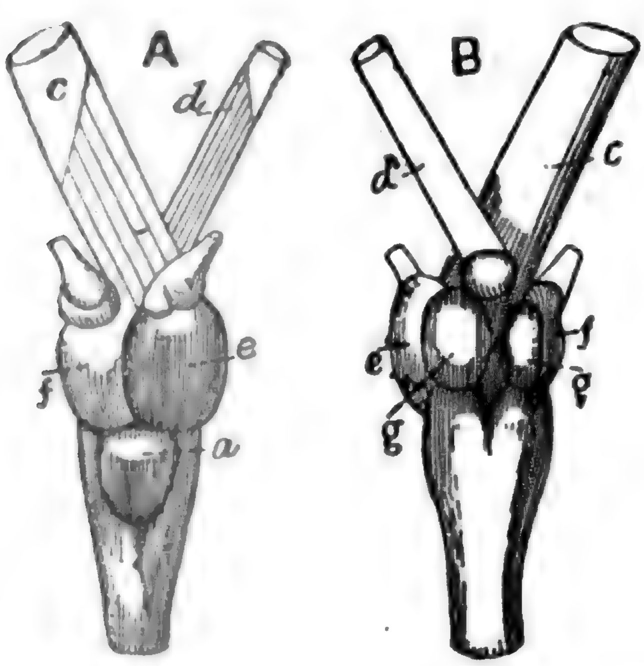

Fig. 81.

Brain of Halibut, a Flat Fish.

A—Top view.

B—Bottom.

c—Optic nerve from left eye.

d-Optic nerve from right eye.

e—*Right optic lobe* of brain in connection with *left optic nerve* and *left eye.*

f—Left optic lobe of brain connecting with right eye.

g g—The hypoaria—the right one the largest.

a—Cerebellum—below which is the tapering Medulla oblongata and upper end of spinal cord.—(*Owen.*)

The difference of strain or attention, exertion and activity forced upon opposite sides of the body, and especially the eyes, has wrought a great difference in the size of the eyes and of the optic nerves, and even of the parts of the brain relating to the eyes. This is shown in Fig. 81. In this case the left eye is the most active, and the optic nerve leading from it to the brain is far the larger; and in like manner the correspond-

ing parts of the brain, viz., the optic lobe on the upper side and the hypoaria on the lower, are much larger than their fellows which are in connection with the right eye.

The flat fishes are destitute of an air bladder so that they remain near the bottom without effort. They are sly and cunning and quickly conceal themselves by burrowing in the sand or mud on the bottom, so that their eyes alone remain uncovered. Both the loss of the bladder and the acquisition of the cunning qualities are due to the habits that their "pursuit of happiness" impelled them to adopt. Finding their best supply of food near the bottom they seldom needed to inflate their bladder, and so it became atrophied. Concealment in the mud not only afforded security for themselves, but deceived the caution of their intended prey. Their human adversaries, however, set their wit at naught by plowing for them with a sort of hooked tool, like a long handled sickle. But when they lay there concealed by mud and the dark pigment which covers their upper side, if any small fish comes incautiously close enough they will dart out and seize it. To watch for their prey they need all their eyes, and so the one which would have been buried in the mud on the underside, has been resurrected and brought to the top. It is easy to imagine how, generation after generation, this twisting process would go on *pari passu* with the constantly changing position of the fish from his original perpendicular, in his efforts to get nearer the bottom; and how the pigments in his skin originally, no doubt, on his back and half way down his sides, as in the Perch, Salmon, &c., shifted over with his eyes to occupy the top side, selection interfering constantly to preserve for survival those best concealed, that is, those in which the deformity had made the most progress and which were able to lie the flattest on the bottom. Of the flat fishes (or Pleuronectidæ) the Plaice, Flounder, Dab, Laminder, Halibut, Sole, Monochirus and Achirus are Rights, that is, have the right side up; while the Turbot, Brill, Topknot, Whiff, Scarlet fish, &c., are Lefts. I conjecture that both the "doubles" and the reverted individuals may be hybrids or crosses.[1]

The question might be asked why or how such a distinction as that between the right hand and the left could occur; why the one should take the lead and the other always accept a subordinate position. At first sight it would seem that the external stimulus ought to act alike on each and that one would naturally be as dextrous as the other. But reflection shows it to be impossible. Suppose the external stimulus resolved, self-co-ordinated and equilibrated in the balances of the brain, requires the driving of a nail. It is a single stimulus but it is made up

[1] An article in Pop. Sci. Magazine, Vol. 27, published since the above was written, takes much the same view of the flat fish as that given here, and adds that the flat fish is derived from the Cod family.

of details, and the reaction must be in corresponding detail. There must be repeated blows with the hammer, and the nail must be held in position till started. One hand must hold the nail and the other the hammer. If this is the first mechanical work of the two hands and they are absolutely alike in dexterity, or the want of it, yet the necessity for *choice* of one of them to hold the hammer and the other the nail is equally absolute. This *choice* is one of the details of the stimulus and will determine itself possibly by a very small majority one way or the other; possibly by the fact that one hand is nearer the hammer and the other nearer the nail. Which ever gets the hammer is thenceforward the dexter hand and that of the nail the sinister. I say thenceforward, because the moment the first nail is driven the two hands are no longer alike, they have become differentiated. And on a repetition of the stimulus it will find one more ready to respond to the hammer part of it and the other the nail part of it. Where the stimuli are of a simple nature confined to causing such reactions as locomotion merely, or sensation, they affect each side more nearly alike than where the movement in reaction is complicated and detailed. From all which it is easy to see that while the two sides must be developed into a complementary resemblance, yet they cannot possibly be precisely alike. It being settled that one side shall take precedence of the other, the social habits of man coupled with the economic advantages of uniformity, the choice has generally fallen upon the same one, by chance the right side, although we read of an ancient tribe of barbarians that unanimously gave preference to the left.

A writer in the *American Analyst* ascribes the preference given to the right hand to the fact that the heart is situated on the left side, and that the early man, in his combats with his fellows for the purpose chiefly of settling who should be the head of the family and boss of the harem, would instinctively guard that most vulnerable spot with his left arm, which habit would devolve all the active fighting on the right hand and arm. Having become dextrous in fighting it would be also dextrous for work. Such habit would at least be contributory. But our ape ancestors used their hands to grasp and fight with before the heart had assumed its present exposed position, and we might conjecture that the already dextrous right hand was not passive enough to do its share in guarding the heart, which in consequence shifted over to the shelter of the left, under the law of selection. At any rate there is evidence that the heart has been influenced by the unequal activities of the right and left sides, because while there are usually *three* cardiac or heart nerves on the *right* side, called the superior, middle and inferior, there are seldom more than *two* on the *left*; viz., the superior and middle, the inferior being left out. This want of symmetry must have been brought

about since the race began to make more use of the right hand than the left. Occasionally the whole six nerves are developed, a circumstance due to arrested development.

The *Narwhal*, a cetacean mammal which grows to be twenty or thirty feet long, has in infancy the germs of two horns, one from each intermaxillary bone. As a rule, however, one of these—the right one—is suppressed, its gelatinous core being supplanted and smothered by a growth of ivory. The left one, however, is developed into a straight horn from six to ten feet long, grooved spirally.

Certain others of the Cetacea—the Cachelots—are unsymmetrical. They have only one blow hole, the left one, instead of the usual two, and the left eye is often much smaller than the right, so that whalers always try to attack that blind side. Many snakes possess but one lung. In some cases where there are two, one is large and useful and the other rudimentary and functionless. This obviously retrograde character of these organs is, as might be expected, associated with degeneracy of the bilateral limbs. One genus of the Orvets (Pseudopus) has no visible limbs except two little bones which form small prominences where the thigh bones should be. But under the skin they have pelvis and shoulder bones. Their lungs are double, but one is one-fourth shorter than the other. Others of this family have no vestige of outer limbs, a circumstance accompanied by a still greater disparity in the lungs. The ear also appears to follow the gradations of the lungs. In the best developed, the tympanum lies upon the outside, but in the most retrograde it is sunk in the head and permanently covered with skin. Other serpents have rudimentary limbs under the skin, and in some, small hook-like hind limbs project outside the skin. In these the lungs are very unequal in size and in many there is only one lung.

In most of the Amphibians the lungs are equal in size, but in the members of the snake-like group Gymnophiona, the right lung is much reduced and these animals are destitute of limbs. The same characteristics extend into the snake-like genera of the saurian reptiles. The Seps, the Dipodes, Chalcides and Chirotes are all mutilated in their limbs, and some of them are destitute of hind limbs, others of fore limbs. In some the organ of hearing is retrogressive. In all, the lungs are irregular and unequal, and in some one lung is reduced to a mere rudiment. It appears from this that the loss of the bilateral limbs is accompanied with the loss of the bilateral quality of the lungs and confirms the position taken above that the conversion of single internal organs into double ones is due to the action of the two-sided activities of limbs, &c., in the first place.

The case of the Chameleon shows still another peculiar relationship. This reptile has only one lung, and it is an immensely large one, but it

has four limbs, and two large eyes. Its ears are covered under the skin, or wanting. But notwithstanding its apparent external anatomical symmetry the effects of a want of correlation are apparent in its functions. The two sides of the animal seem to be, to a great extent, independent of each other. One side may be asleep when the other is awake. One eye may look in one direction and the other in another at the same time. The tongue is single and exceedingly quick, the only quick organ it has, for the limbs are exceedingly slow, and "unlike most other animals, the Chameleon is totally unable to swim, from the incapability of its limbs of acting in due concert" (Cuvier). The large, single lung appears to relate chiefly to the active, single tongue, and the activity of the animal is chiefly *median* instead of bilateral.

Mention is made elsewhere of the case of a female Deer possessing a single horn in correlation with an aborted ovary. The case illustrates the degree of independence which may exist between the two sides of the bilateral body, and also the fact of the individuality and self sufficiency of one side by itself. This is also illustrated, and better, by the fact that among birds generally, although the female has two ovaries with oviducts, only one of each is developed into a useful organ, one ovary and one oviduct being reduced to mere rudiments. Same is true of the Ornithorhynchus, as shown above, Fig. 79.

CHAPTER XXII.

OSSEOUS SYSTEM.

The mechanical strains put upon an animal body when it is made to move, are of two kinds, tension strains and compression strains, or strains of pulling and strains of pushing. The simplest spec of protoplasmic life that moves is under obligation to this mechanical law or necessity equally with the most elaborate vertebrate animal. The parts of the body upon which each of these two classes of strains falls is determined by the direction from which it is assailed by the external stimulus. Whenever a muscle is stimulated it contracts lengthwise, pulling the ends together. This is a tension strain. When the muscles on the right side of a fish are irritated they contract and shorten that side, causing the head and tail to approach each other, and giving a concave shape to that side. An irritation on the left produces a converse effect. But notwithstanding alternate vigorous pulls of the head toward the tail, the fish is not shortened because these tension strains are thrown primarily upon the backbone, a rigid strut that cannot be compressed longitudinally. So the energy of the tension strain is transferred to motion in the direction of the least resistance; viz., a deflection of the

head and tail alternately towards one side and the other, which being transferred in part to the water, ends in the progressive movement of the fish. It is manifest that the first effect of every muscular tension is a compression, or at least a compression strain, on some other part. In the fish, even if it had no backbone, the compression strain would necessarily come where the backbone is, since the tension being necessarily bilateral, oscillatory and alternate, the muscles of the opposite sides would alternately pull down upon that middle axis like playing at see-saw. If that middle axis were muscle instead of bone, from its very position it could never be called upon to perform the work of a muscle, that is, contract, because its contraction could add nothing to the locomotion of the fish. It would therefore remain rigid and functionless as muscle, and, in time, lose its power of contraction. Everybody knows the indurating effect of pressure upon the skin in the horny hands of laborers, the soles of people who go bare-footed, the callosities of monkeys and cavalry-men, and the thick necks of the working oxen. Tissue formed under pressure must of necessity differ in texture from that thrown together without pressure. The difference between the hard, compact muscles of a laboring man and the soft, flabby muscles of the man who does nothing, is caused by the packing of many cells of muscle tissue in a small space when exercise causes the frequent and vigorous contractions of the muscle fibres. Every installment of blood drawn by the irritation to the excited tract, deposits fresh particles of nutrient matter, and every contraction of the muscle fibres packs them down, as it were. Tendons and ligaments are bands of dense fibres of that connective tissue which fills the spaces between the muscles and surrounds the bones. There can be no reasonable doubt that the constant tension strain upon the tendons, coupled with the rigidity and fixedness of their position, has mechanically packed their fibres together.

The ligaments are subjected to both tension and compression strains.

The connective tissue also grades into gristle or cartilage possessing some elasticity, and subjected chiefly to compression strains. Bones are formed by the deposit of phosphate and carbonate of lime among the organic cells of cartilage, subverting the greater part of its elasticity and giving greater density and rigidity to its structure. Cartilage is, therefore, the incipient stage of bone. In the young or larval Ascidian, the Amphioxus and the Selachian fishes (Sharks, Dog-fishes, &c.) the osseous system remains in the cartilaginous stage. But in all the other vertebrates most of the skeleton becomes ossified, although there remain in all of them some parts which never do.

In the embryos of all vertebrates the skeleton begins as gelatinous cartilage, and the ossification of the different parts takes place at different times. At birth, the bones of human infants are soft and flexible;

there are six fontanelles or spaces between the edges of the skull bones covered by cartilaginous membranes instead of bone[1], and the innominatum, or hip bone, is then in three pieces, the ilium, ischium and pubis. The fontanelles close up with bone during infancy, and during childhood the three bones of the innominatum are consolidated into one. The sternum in youth is also in three pieces, which are consolidated in advanced life.

The coccyx, or tail bones, four in number, are separate from each other in infancy but generally consolidate with age. As age advances, the bones become harder and less elastic, and ossification is liable to extend to cartilages, especially in the ribs and larynx.

The whole development of cartilage consists in a gradual packing and hardening of tissue, brought about by mechanical compression under stimulus and work, the habit of growth of each age tending to perpetuate itself by hereditary transmission.

The first *cartilaginous* formation in the body is that of the seven neck or cervical vertebræ. But the first *ossification* in the body is that of the clavicle, or collar bone.

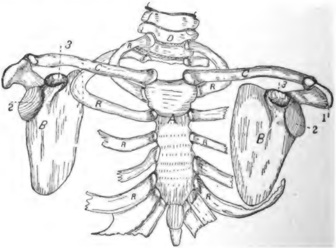

FIG. 82. *Human Pectoral Arch.*

A—*Sternum* (breast bone).
B—*Scapula* (shoulder blade).
C—*Clavicle* (collar bone).
D—Upper part of *back bone.*
R—*Ribs.*
1—*Acromion* process of shoulder blade articulating with clavicle.
2—*Glenoid Cavity.* Place where the arm is attached.
3—*Coracoid* process of the shoulder blade (or raven's beak).

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[1] The skull of Selachian fishes retains the fontanelles during life.

In some of the lower vertebrates parts remain cartilaginous which are ossified in the higher. In some of the teleostean fishes, as well as the cartilaginous, some bones of the skull are not ossified but remain cartilaginous. This is also true of the frogs, the bones of the head being only partly ossified, even in the adult. But the bones of the limbs of the frog indicate the activity of the animal—especially the hind limbs, in which the tibia and fibula are fused together into one, as in the horses, while the fore limbs are braced apart by very strong coracoids. The backbone of the Ganoid fishes remains always cartilaginous, while some of the ribs may become ossified.

The position of bones in the body of the vertebrate must therefore indicate the points where, in the working of the machine, the compression strains finally bring up. The comparative anatomy of the shoulder and pelvis bones, which furnish support to the limbs, illustrate this.

The pectoral arch consists in man of the scapula or shoulder blade, the clavicle or collar bone, and the sternum or breast bone—the first two paired, the last one single, five in all. The clavicle is attached at one end to the outer angle of the spine of the scapula to what is called its acromion process, at the tip and rear of the shoulder, and extends from there to the breast bone with which it articulates. The effect of these clavicles is to hold the shoulders apart and the longer they are the greater is the breadth across the shoulders. They resist the compression strains that are generated by most of the movements of the arms. The heaviest work of civilized man, which is lifting, generally tends to pull the shoulders together, thus throwing a compression strain on the clavicles. Swinging by the hands, as is the practice of the ape and monkey tribes, and such movements as swimming, pushing sideways, and, in short, nearly all our movements involve a strain of compression often alternating with one of tension, upon the members of the pectoral arch. There is a stout ridge of bone running diagonally across the back of the shoulder blade to which large muscles are attached. This is called the spine of the scapula, and the outer and front end of it forms the acromion process mentioned above.

Just inside of and to the front of this is another "process" of the shoulder blade, projecting forward, which is called the coracoid process. It serves in man, apes, &c., as a place for the attachment of some muscles and ligaments.

But this is a piece of bone with a history. On comparison with other animals it is found that this coracoid process is a remnant of a bone which, in some of our vertebrate cousins, extends from the scapula to the sternum nearly parallel with the clavicle, and serving the same general purpose, except that the strain it sustains is further down the chest, as its articulations at the ends are both lower than those of the clavicle.

Whenever the fore limbs are pulled forward over the head or across the chest, or at any angle between the two, a compression strain is thrown upon the parts occupied by these bones; but when the limbs are pushed in the contrary direction the compression strain is thrown upon the scapula. It is obvious, therefore, that the movements of the front limbs in swimming, flying and climbing, or swinging by the hands, will tend to develop either the clavicle or coracoid, or both, while walking on the fore limbs will develop only the scapula. The cartilaginous fishes, Sharks, Rays, Chimera, &c., furnish a sample of one of the earliest forms of the pectoral arch. The bones are not ossified and the three bones on each side are represented by a single piece of cartilage. These two lateral cartilages are joined together in the middle line in front. They therefore occupy the territory and serve the same purposes that are accomplished better in the more advanced development of the parts. In the Teleostean, or bony fishes, the divisions of the pectoral arch are, in general, fairly established, and the scapula coracoid and clavicle are distinct from each other. There is, however, more or less variation in forms, often some additions and membranous appendages, and often the clavicle is not ossified but remains a *membrane* bone. In the mud-fishes (Lepidosiren) the pectoral arch is chiefly cartilaginous, but the different parts practically represent the same pieces as they occur in the other fishes. (Their fins are long and thread-like.)

The Amphibians (frogs) also have all the parts, but the coracoid is much more largely developed than the clavicle. It is, in fact, a broad,

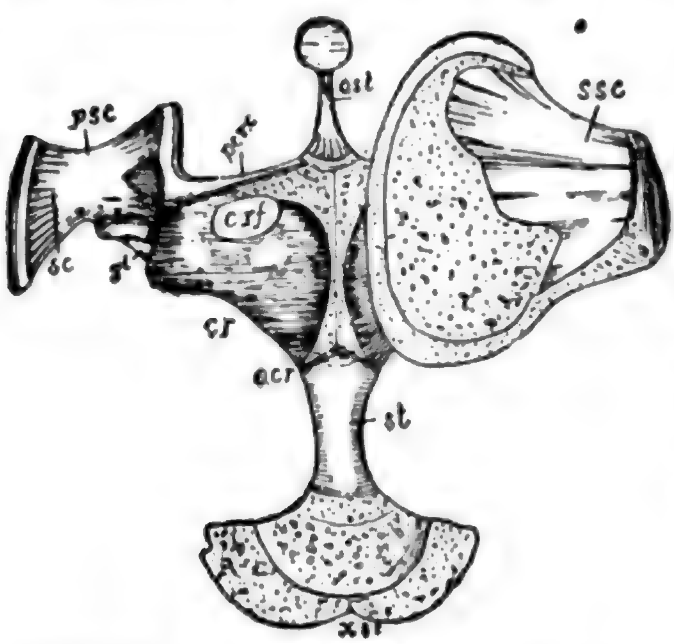


FIG. 83.—*Sternum and Pectoral arch of Frog*, as seen from *above*, the left supra scapula removed.
sc.—Scapula.
ssc.—Supra scapula.
psc.—Prescapular process.
cr.—Coracoid.
ecr.—Epicoracoid.
crf.—Coracoid fontanelle.
prc.—Precoracoid with clavicle.
ost.—Omosternum.
xst.—Xiphisternum—a *sword shaped* cartilaginous appendage to sternum.
gl.—Glenoid cavity, place of attachment of arms.

triangular plate with its base on the median line of the chest and its apex articulating with the scapula. It contains a fontanelle or open space at a point obviously free from strain, and its anterior edge is bounded by the clavicle.

The Lizzards generally possess well developed clavicles and coracoids, but the Crocodiles have only the coracoids, and are devoid of clavicles.

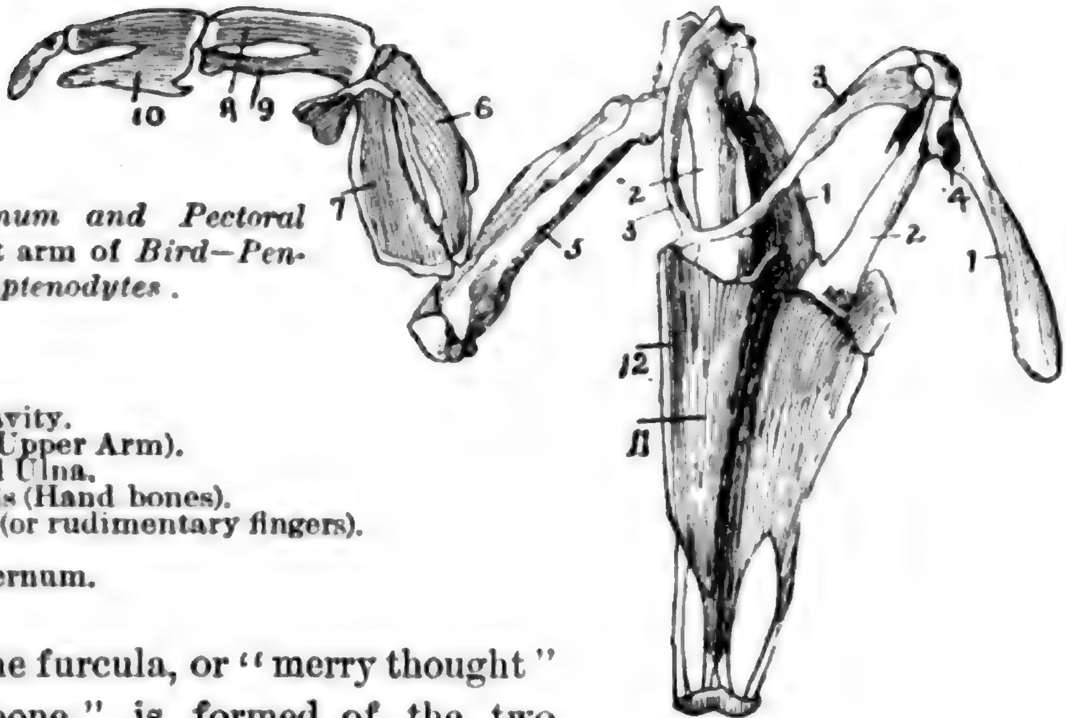


FIG. 84. *Sternum and Pectoral Arch* and right arm of *Bird—Penguin Aptenodytes*.

1 1. Scapula.
2 2. Coracoid.
3 3. Clavicles.
4. Glenoid Cavity.
5. Humerus (Upper Arm).
6. 7. Radius and Ulna.
8. 9. Metacarpals (Hand bones).
10. Phalanges (or rudimentary fingers).
11. Sternum.
12. Keel of Sternum.

In birds the furcula, or "merry thought" or "wish bone," is formed of the two clavicles joined together in front instead of being separately articulated with the sternum.

The scapula and coracoid together form the L-shaped bone on each side of the neck, the coracoid part being the stout heavy end which is joined to the sternum in front and serves, with the clavicle, to keep the shoulders apart against the powerful compression strain caused by the action of flying. The flat, blade-like end of the L is the Scapula, or shoulder blade. Parrots, however, have a weak furcula or clavicle, and some paroquets none at all, while those of the Toucans are not connected in front, but subsist as a pair of straight and sharp practically useless rudiments. But in these birds the coracoids are well developed. In the extinct Pterodactyls, the parts are similar to those of the Parrot, &c., in having no clavicles, but possessing the coracoid.

The Monotremes, Echidna and Ornithorhynchus, which possess so many bird and reptilian characters, resemble the birds, amphibians and lizzards in the form of the pectoral arch, the coracoid being large and articulating with the sternum, and also possessing the attachment found in Amphibia known as the epicoracoid. Their clavicles also are peculiar in being articulated in front to a T-shaped inter-clavicle, which is found in no other mammals but which is a reptilian feature, and is represented in the skeleton of the extinct reptile Ichthyosaurus.

In none of the rest of the mammals does the coracoid articulate with the sternum, but where there is any at all it appears as only a remnant attached as a process to the scapula. The only strut left between the scapula and the sternum is, then, the clavicle, and in many tribes even that is discontinued. In the Marsupials (Kangaroo, &c.), the coracoid is a considerable rudiment but does not come near the sternum.

Of the Edentates some of the species possess clavicles, for example,

the climbing Cyclothurus didactylus, South American Ant-eater, while other species do not have any.

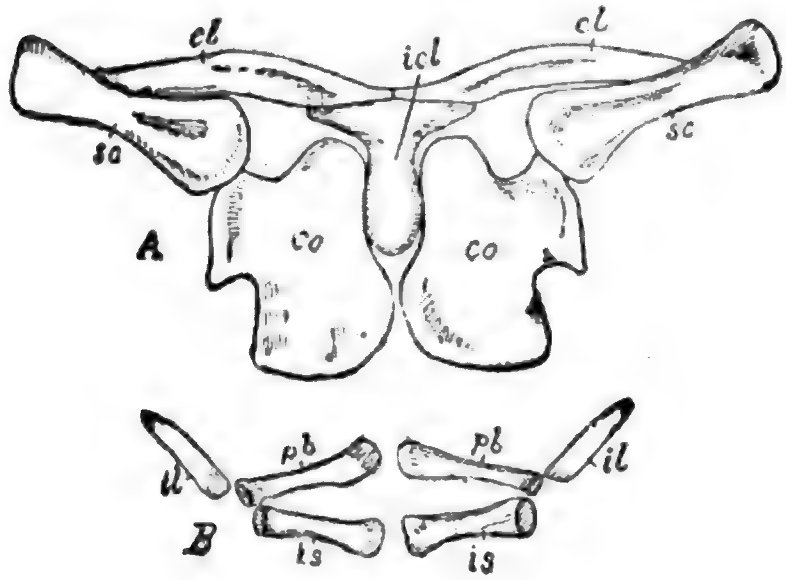


Fig. 85. Part of Skeleton of *Ichthyosaurus* (*Extinct Gigantic Saurian.* (*After Huxley.*)

A—Pectoral Arch.
co, Coracoid.
sc, Scapula.
cl, Clavicle.
icl, Inter-clavicle or Episternum.
B—Pelvic Arch.
il, Ilium.
is, Ischium.
pb, Pubis.

The rodents, Squirrels, &c., generally possess clavicles, but the Guinea-pig is an exception.

Clavicles are completely developed in all the Insectivora except *Potamogale.* In the Moles they are very strong.

In the cheiroptera, Bats, &c., the clavicles are remarkably long and strong, and the broad scapula has a strong spine.

The Apes and Man possess clavicles and the coracoid rudiment. In all the cases cited above of animals possessing coracoids or clavicles or both, the fore feet or hands are used for other purposes besides walking—as swimming, flying, climbing, digging, grasping, etc.

But now, coming to animals whose chief use of the fore limbs is in walking, we find things different. In all the carnivorous animals the clavicle is incomplete. In the dog it is represented by a gristle.

In the carnivores, generally, the clavicles are more or less rudimentary, and when ossified at all are simply suspended in the muscles and not articulated to the sternum. This family includes the Bears, Raccoons, Badgers, Weasels, Martens, Otters, Skunks, &c., as well as the Dogs, Wolves, Foxes, Hyænas, Cats, Lynxes, Lions, Tigers, Panthers, &c. Some of these animals do more or less digging and burrowing, while others are fair climbers. Yet the burrowing of most of them extends no further than the excavating of one or two holes during a lifetime, and their climbing, to an occasional dash up a tree; not comparable, in the first case, to the life-long tunnelling of the Mole for his daily bread, or, in the second, to the perennial leaping and swinging of the Apes from branch to branch.

The case of the Ungulates, or hoofed animals, is much more pronounced, for they do not, in any case, possess clavicles. These animals are divided into the Pachyderms, which include the Elephant, Pig, Hip-

popotamus, Rhinoceros, Peccary, Wart-hog, Tapir, Horse, Zebra, &c., and the ruminants which embrace the Camel, Lama, Musk, Deer, Stag, Antelope, Sheep, Goat, Buffalo, Giraffe, domestic Ox, &c. As their fore feet are used for walking exclusively, and constantly support the weight of the animal, the compression strains are thrown upon the scapula, which is developed in all, and a tension strain is thrown upon the part usually occupied by the clavicles. The Horse, Pig, Hippopotamus, and Tapir (and doubtless others) possess a remnant of the coracoid reduced to a mere tubercle. The Hippopotamus also has a short acromion process or prolongation of the spine of the scapula, to which the clavicle would be articulated, if there were one. Related to the ungulata are the herbivorous sea mammals, the Manatus or Mermaid, and the Dugong or Siren. These are destitute of clavicles like the rest of the ungulates, but their scapula possesses a spine.

The Cetacea (Dolphins, Porpoises, Whales, &c.)—sea mammals—are also destitute of clavicles, but some of them have straight and flattened *coracoids.* These animals are descended from land mammals, which probably did not possess coracoids, but having again taken on a habit of swimming, they are, doubtless, in process of reacquiring these parts anciently developed in the lower vertebrates by that habit.

In examinations of this kind it is not always practicable to determine how much of a given characteristic is due to the habit as practiced by the present generation, and how much to a different habit practiced by its remote predecessors. An individual may now have a habit that is in antagonism to the habits of his ancestors, and, therefore, is tending to undo the anatomical development which they built up. When we find a fish on land, walking across the country on its fins, we will not conclude that the fins have been differentiated into their present shape by walking. On the contrary, we should suppose that such habit in the fish is a new one not indulged in by the ancestors in whom the fins were developed, and that, if persisted in during a sufficient number of thousands of generations, might be expected to have a modifying effect on the shape and functional value of the fins. Many of such points can be settled by comparative anatomy. We should hardly have been able to discover that our "coracoid process" was a remnant, which for some millions of years has been on its road to extinction, if we had not been able to see a perfect original in our lower vertebrate cousins. We might have supposed, in the absence of such testimony, that our present habits were such as to develop such a "process" *up* from the scapula. But now we know that it is the other way, and that the coracoid has been developed *down* to become the "process."

The future of comparative anatomy is destined to make us acquainted with our anatomical history in detail, to point out the relationship and

pedigree of every bone, muscle and nerve, and at the same time disclose not only the general habits of our variously formed ancestors, but determine the exact nature of the stimulus to which each part has been subjected, and reduce it to its mechanical value, even as an engineer constructs a strain sheet for a truss bridge. As yet, we can only catch

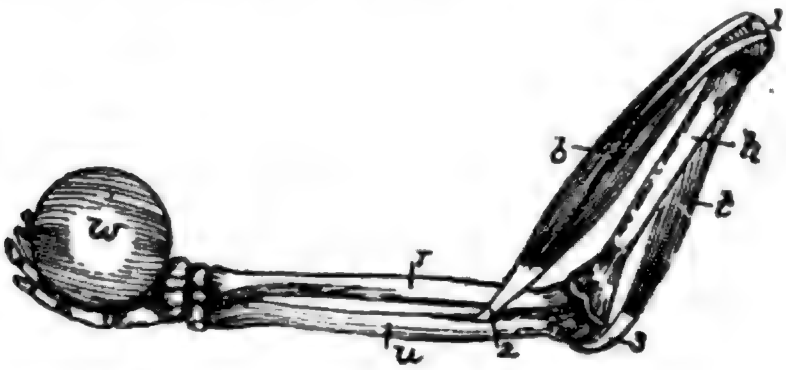


FIG. 86. *Diagram of Arm of Man.*

h—Humerus. *r u*—Radius and Ulna. *t*—Triceps muscle. 3—Its tendon. *b*—Biceps muscle. 1—Its attachment to the shoulder. 2—Its attachment to the ulna.

While the biceps is rigid the weight puts a tension upon it and a compression strain on the humerus. When the biceps contracts the weight is raised.

on to a few of the most obvious points, but still enough to give a very certain clew to the principle of differentiation, which we may safely assert to be *habit.*

And habit may be defined to be a monotonous repetition of identical reactions against the same constantly recurring stimulus. The stimulus is the cause of the habit, and it must be constant over a considerable

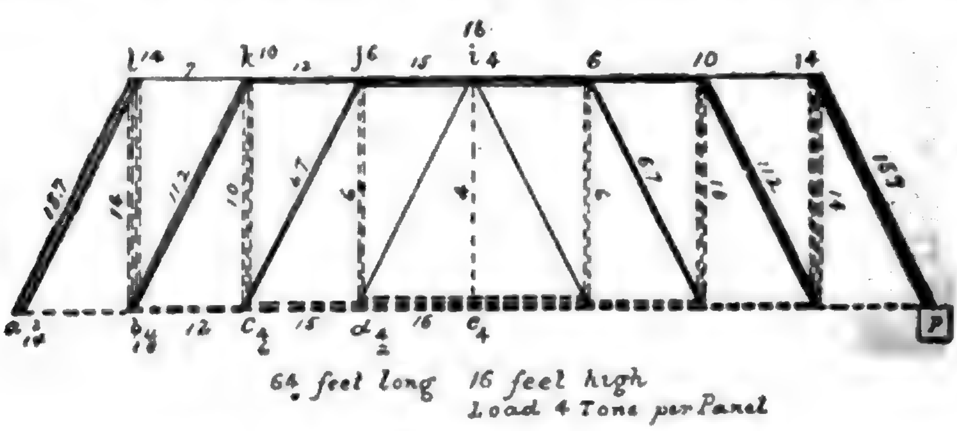


FIG. 87. *Strain Diagram of a Bridge.*

The broken lines are the parts subjected to tension strains—they are the *muscles* of the bridge. The unbroken lines receive the thrusting or compression strains and are its *bones*. The figures indicate the amount of strain in tons on each member. (*Trautwine.*)

e i, 4 tons.	*i d*, 2.8 tons.	*a b* or *l k*, 8.5 tons.
d j, 6.5 "	*j c*, 8.39 "	*b c* " *k j*, 14.75 "
c k, 11.5 "	*k b*, 13.98 "	*c d* " *j i*, 18.50 "
b l, 16.5 "	*l a*, 19.01 "	*d e* 19.75 "

period of time in order to produce permanent perceptible anatomical effects.

When there is a change in the stimulus, habits change rapidly to suit, and we may be sure that the effect on anatomical structure likewise begins at once. But much molecular change may take place before it becomes apparent to our senses or even to scientific tests.

It is possible that a habit may not appear to agree precisely with the present structure of the individual, and if it does not, it is evidently working a change in such structure. It is to habit under stimulus, therefore, that we look for the origin and cause of all differentiation. The history of differentiation is, therefore, the history of habit, and the history of habit is the history of stimulus. This statement appears obvious on its face, but it may not be readily realized how much it implies and how far it leads, which will appear, however, as we go on, with further illustrations.

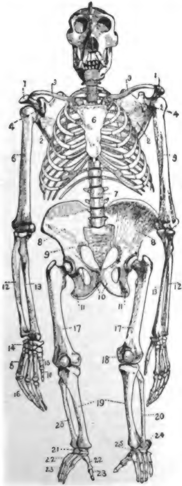


FIG. 88.

FIG. 88. *Skeleton of Gorilla engena.*

1—*Acromion process of Scapula.*
2—*Scapula.*
3—*Clavicle.*
4—*Coracoid process.*
5—*Humerus.*
6—*Sternum.*
7—*Spine.*
8—*Ilium.*
9—*Sacrum.*
10—*Pubis.*
11—*Ischium.*
12—*Ulna.*
13—*Radius.*
14—*Carpal bones.*
15—*Metacarpals* (hand).
16—*Phalanges* (fingers).
17—*Femur* (thigh).
18—*Patella* (knee pan).
19—*Tibia.*
20—*Fibula.*
21—*Tarsal bones.*
22—*Metatarsals.*
23—*Phalanges* (toes).
24—*Calcaneum os calcis* (heel bone).
25—*Astragalus.*

If the pelvic arch, including the hip bones, &c., had always affected the same habits as the pectoral arch, we should find it possessing the same construction. At the outset the two were much alike in function, and, consequently, in form. In the Selachian, or cartilaginous fishes, the pelvic arch consists of a pair of cartilaginous plates much like those of the pectoral arch. They are, in some cases, joined together in the abdominal front, and, like those of the pectoral arch, they support the fins. When, in the osseous fishes, the cartilaginous arch becomes broken up into parts, these parts correspond with those in the pectoral arch, the ilium answering to

the scapula, the ischium to the coracoid, and the pubis to the anterior coracoid, or clavicle; the parts being thus arranged from front to rear, in the same order at each end of the animal, as if precisely the same muscular movements were required and the same sort of strains imposed at each end. But that divergencies should take place between the two ends was as inevitable as that they could not possibly be always subject to the same sort of stimulation. Like the fore wheels of a wagon, the fore limbs of the vertebrate must steer the animal, exerting their muscular force in many various ways to give the head new directions, while the duties of the hind limbs are much more monotonous. The skeleton of the fossil ancient reptile Ichthyosaurus shows how far such divergence was carried in a class of animals whose chief movements were connected with swimming. But in the land vertebrates, whose habits require such different services from the limbs at either end of the body, we find the greatest divergence of structure, a divergence caused, however, in much the greatest degree by alterations in the pectoral arch. For throughout the class there is a striking sameness in the number and character of the pelvic bones. They vary in size and strength in relation to the strain put upon them.

In the enormous fossil Megatherium, which is supposed to have had the habit of throwing its whole weight upon the hind legs while securing its food from the branches of trees, the pelvic arch is proportionally very strong and wide. It is also strong and large in the Kangaroo which stands upon and leaps with its hind limbs. The same is true of most of the rodents (Squirrels, Rabbits, &c.), animals that run by springing from their hind feet, rather than by creeping. In the erect Apes, and still better in Man, the pelvic bones form a basin, as the name implies, very well adapted to receive the falling viscera of a four-legged animal assuming an erect position.

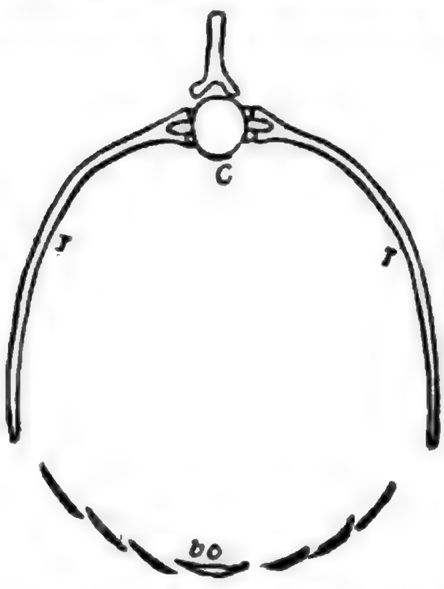


FIG. 89.

FIG. 89.—Ribs of *Ichthyosaurus.*
C.—Centrum of backbone.
rr.—Ribs.
vo.—*Ventral Ossifications.*

The common Sloth, (an Edentate), lives upon trees, suspended on the underside of branches around which he clasps his hind legs and feet, and one of his fore legs or arms. With the other arm he reaches the leaves on which he feeds. In consequence of this habit the pelvis is large, and the thighs are directed outward, so that the knees cannot be brought together. The arms are very much longer than the legs. He is extremely slow and awkward anywhere but in the trees in which he lives, but is extremely well fitted for his habit of life.

The first ribs of the chameleons are joined in front to the sternum, but the rest are joined each to its antagonist, so that each pair forms a hoop.

In the crocodiles there are the ordinary true ribs which articulate in the ventral (front) side of the animal with the sternum, and the false ribs which are connected (on each side) with each other at their extremity by cartilage, and besides these are others which protect the abdomen by being buried in the muscles across the ventral parts but do not extend to the spine at either end. "They appear to be produced by the ossification of the *tendinous extremities* of the *straight muscles.*" (Cuvier, Animal Kingdom, p. 261.) It would appear that animals, whose abdomen rests more or less completely on the ground, by such habits differentiate muscle fibre into rigid bony tissue capable of resisting pressure. And that they should take the shape of transverse ribs instead of plates, is obviously a consequence of the lateral oscillation of the body from side to side in turning and bending, by which the materials of the tissues are compressed into transverse creases of varying density and again stretched with varying elasticity; a process which consigns certain tissues to an abnormal molecular activity, by which the usual nutrition of muscle tissue is prevented or suspended, and a diseased or unusual deposit of organic or mineral matter introduced. It may seem strange to class a new and useful differentiation as a disease; but any change by which a hereditary race structure is in any degree subverted must be classed as abnormal and therefore a disease. But the question of its usefulness, which cannot be predetermined, is settled subsequently by that process of *actual experiment* called *natural selection.* If the disease proves a useful innovation by which the animal reacts more readily than before against the stimuli of his environment, he lives and transmits his peculiarity which thereafter becomes the normal property of the race. Otherwise it may be fatal to its possessor and die with him, or if not a vital matter and yet not useful it will be discouraged by a habit contrary to that which developed it, and so disappear after a generation or two. This view finds support in the medical theory of tumors and other abnormal formations. Tumors are held to be caused by the growth of dormant embryo cells in spots where the normal activity and nutrition of the tissues is suspended. And such growth may become hereditary, and children born generation after generation with tumors in the same locality.[1] Cartilage from a fœtus may be artificially transplanted into the tissues of a mature animal and there grow into a cartilaginous tumor. Cancer is the growth of an epithelial tissue in places where from some habit of the body the usual tissue nutriment is not supplied, perhaps not required.

[1] Pepper's System of Medicine, 106.

Gout consists chiefly of a deposit of urate of soda in and about the joints, and sometimes other parts of the system. The small amount of urate of soda produced in the system in ordinary health is constantly carried off in the excretions. But the quantity generated in persons indulging in high living is greatly increased. If this increase is accompanied by a diminution of exercise, by which certain parts cease to be wasted, and so cease to receive their quota of proper nutriment and thereby become centres of inactivity, the foreign matters are excreted upon these parts instead of out of the body. They become a receptacle of garbage—a sort of dumping ground. This disease is often hereditary and occurs in young persons when inherited, but is not acquired before the age 35 when not hereditary.

These facts show that new formations—even malformations—may possess vital and reproductive functions. And it is not to be predicted whether such new formations shall continue or not. That point is settled by the subsequent action of the environment, and the sort of habits it puts upon the organism.

The calcareous shells of marine animals, and the pearls found in certain bivalves, are composed of excremental substances. The matter composing the shells is deposited in the space under the skin, a place of deposit that, proving of service in the preservation of the animal, has become hereditary and normal.

The abnormal deposit of the matter composing the pearls, is no advantage to the animal, but rather a disadvantage, since they are hunted for its sake. Nevertheless, certain tribes are more or less subject to the disease, and it is, doubtless, more or less hereditary. Pearl-diving is as if some superior race should swoop down on our planet for the purpose of securing human beings possessed of the most beautiful cancers.

It appears to me no violent assumption to suppose that the deposit of gelatinous and of inorganic matters in parts of muscular and other tissue, in which the normal activities and renewals of such tissue had become suspended, was the origin of the osseous system. And that such primary abnormal deposit being subsequently subjected to the utilitarian test and not found wanting, was selected by natural causes as a permanent feature of the organism. All subsequent modifications caused by modified habits whereby the system has been extended or curtailed, have originated as deformities or diseases, have been likewise subjected to the test of natural selection, and have survived only because useful to their owner.

The pelvic arch has, in certain animals, a remarkable modification in the possession of what are called the marsupial bones. These are two long, blade-like bones that articulate with the pubis in front and run

forward so as to support the contents of the abdomen and protect them from outside pressure. They appear to answer the same purpose to the abdomen that the sternum does to the thorax. These bones are developed in the Monotremes (Ornithorhynchus, Echidna, &c.) and in the Marsupials, or pouched animals, and rudiments of them are found in some of the carnivores.

These bones are very ancient, as they are found in the great Dinotherium in the middle Tertiary formations of India. It is reasonable to conclude that they are the remains of pelvic plates which originated in the crawling reptiles and were formed at that end of the animal, as the breast bone was at the other end. Probably when they were at their highest point of development, the lumbar ribs articulated with them (or *it*, if it was all in one) as the dorsal ribs do with the sternum. But when the descendants of that crawling animal ceased to press their bellies to the ground, and began to walk, supported by their legs, the compression strain was taken off that part of the body and the pelvic, sternum and lumbar ribs became reduced, and in many cases obliterated. The relics of this pelvic plate retained by the Marsupials, is of service to them as they are subject to an exceptional pressure upon that part arising from the marsupium, or pouch containing the young. Yet the male Marsupial has no pouch, although he possesses the bones. The bones cannot be essentially marsupial bones, since animals without a pouch possess them. On the other hand, there are other animals beside the Marsupials that have a pouch for sheltering their young; viz., the *male* pipe fish (Syngnathus) and some female Amphibians—(*Notodelphys*, *Pipa*).

That the first mammals have these bones is very suggestive of the origin of the mammal tribes from reptiles that pressed their bellies to the ground.

The fact that those mammals which do not need the coracoids, the clavicles or the marsupial bones, still possess remnants of them, proves them to be derived from a line of ancestry in which they have been useful, and, in short, is one of the many facts that establish the common origin and blood relationship of all mammal life. And it also proves that since they all started from a common anatomical structure and habits, and afterwards parts of the structure became rudimentary with a change of habit, therefore the change of habit was the cause of the retrogressive change of structure. The other alternative to this position would be that functionless and useless rudiments are created by supernatural intelligence, which is an absurd conclusion even, from the argument that a fitness implies a designer.

The flying squirrels have on each of their flanks a wide expansion of the skin which extends from the fore to the hind leg. This is covered

with hair and appears to be simply a fold of their ordinary skin projecting from each side. This arrangement makes the little animal nearly three times as wide, and enables him to make long flying leaps.

On their feet they have long bony appendages which assist in supporting these expansions of skin.

There can be no doubt that this flying apparatus, including the bony supports, have been developed by the leaping habits of the animal. In much the same way were the side and median folds of the skin in fishes developed, which subsequently became specialized into dorsal, ventral, lateral and tail fins.

The development of limbs was therefore independent of the backbone, and their attachment to it was a later arrangement. In fact, the scapula and pectoral arch with the fore limbs do not directly articulate with the spine, although the pelvic bones usually do.

In fishes, however, the pelvis bones with hind limb are seldom attached to the spine, but are often placed in advance of the belly and attached to the bones of the shoulders. Sometimes the pectoral fins are absent and then the bones of the pectoral arch are rudimentary and of little or no use.

In tortoises the development of the carapace or shell made an exceptional arrangement of the bones possible. So the coracoid is wanting and the shoulder blade reaches from the carapace to the sternum. That is, there was sufficient rigidity without the coracoid, and so it became obliterated. The scapula and clavicle appear to be fused together. In the true Serpent, on the other hand, there is no shoulder blade, clavicle, coracoid nor sternum. This animal moves without limbs by means of the alternate expansion and contraction of its belly muscles. Such motion as that would be prohibited by such rigid pieces as the sternum, the marsupial bones and ventral plates.

This animal, as well as the Mammal, is a descendant of reptiles with limbs. But while one branch of such reptile stock advanced by using its limbs to lift it from the earth, the other took the retrograde track and suppressed its limbs in its endeavors to hug the earth still closer. The advance of the one would compel the retrogression of the other, whose only safety remained in its becoming inconspicuous, unaggressive, cautious and sly, in the same ratio in which the advancing branch became active, enterprising and aggressive. It is so in human society, too. One wing cannot advance greatly beyond the average without entailing a retrogressive movement on another one. And so the snakes, by the compulsory disuse of their limbs, have lost them.

CHAPTER XXIII.

RESPIRATORY SYSTEM.

All vital activities are carried on at the expense of animal tissue, some of which is broken down with every movement, accompanied with the production of heat. Food is the raw material from which new tissue is formed, and it must be constantly supplied to every animal body in order to keep it running. The force with which an animal moves or which in the shape of heat keeps up the working temperature of his body, is the same force which was consumed in putting together the minerals of which his food was formed. This force was originally the sunlight which, acting through the chlorophyl of plant leaves, extracted carbon from the carbonic dioxide of the atmosphere and packed it away in the tissues of plants. When in the chemistry of the vital processes the carbon is sufficiently reduced to regain its affinity for oxygen, the two are again united to form again carbonic dioxide, and the same amount of force which the sun originally expended in separating the two, is now given up to move and heat the animal.

This union in the animal of oxygen and carbon is, therefore, absolutely essential to its continued activity and even its life. The carbon is furnished by the tissues, the blood and the food, in process of digestion, and the oxygen is furnished by the atmosphere. It is essential, therefore, that the air should be brought into contact with the interior parts of the body. This contact is called respiration, and it is accomplished in every living organism, high or low.

In the lowest organisms, such as the amœba, in which there is no differentiation of parts, the whole body respires, each particle of the surface being in contact with the oxygen of the air. In the more highly developed, some special parts are differentiated and adapted to the special function of admitting the air to contact with the working parts of the body. Most insects have tubes called tracheæ, which extend inward from the surface, to convey the air. Animals that are aquatic must in general depend for their respiration on the small amount of air which is enclosed in the water. This air is brought into contact with the blood by means of cilia in some cases, but generally by gills of one form or another. In some marine worms the gills are in little tufts on each side, one pair attached to each segment composing the articulated body. In others the gills are reduced in number and made more effective, and in the higher worms and fishes are placed near the head. In all cases they are a middle ground, a meeting point for the oxygen of the air and the carbon of the blood, and the principal blood vessels are made to run

by them so as to allow of the transfer of the elements by osmosis through the delicate membranes of the vessels. The difference between aquatic and aerial respiration is one of degree only, the essential principles and end being precisely the same. But it is obvious that an animal breathing air directly will obtain more oxygen than one breathing it through water, and that since the energy liberated for the heat and activity of the animal is in proportion to the amount of carbon oxidized, it follows that the air-breather will be superior in force and activity to the water-breather, other things being equal. And conversely those animals which are compelled by their environment to use greater activity will of necessity seek the more abundant supply of oxygen furnished by the atmosphere. Hence we find in every class of gill-breathing animals, some members of the class whose gills are modified to enable them to take in air directly, instead of depending on the water alone as a medium. This modification in general consists of an enlargement of the gill cavities, and the lining or filling the enlargement with folds of mucous membrane; the new parts being adapted to direct contact with the air, while the gill cavities with the old fashioned gills for water-breathing still remain. This process of enlargement is really nothing more than a continuation of the original modification by which gills were first formed, they being nothing more than folds of the skin subjected to the special function of respiration. The animal possessing the supplementary air-breathing cavity is in reality an amphibian. The transitional stage between those having water gills and those having these additional air spaces is found in the gilled animals that can live where it is *damp* merely. In their case the moisture in the air is sufficient to keep the gills in proper mechanical condition to absorb the air. The land leeches of India are examples of skin-breathing animals that by reason of the moisture of the climate can live on land. Their whole skin is a respiratory surface and ordinarily they are aquatic, but they are extremely numerous on land in India and on the Indian islands, where the skin is kept moist by the saturated atmosphere. They are very numerous on the trees, and drop down upon every thing passing under, so that other animal life is impossible there. (Semper.) The Planarians and Nemerteans, aquatic worms that are also skin-breathers, are likewise able to live in moist places on land. It is well known that many kinds of fish can be carried about and kept alive on land for days if only care be taken to keep their gills moist. The Neretina, a gasteropod aquatic shell mollusk, has species that live mostly on land. Their gill cavities contain a network of blood vessels which are united into one, that communicates with the auricle of the heart, an arrangement equivalent to lungs for air breathing. In addition to this it has gills which it uses in the water, where it goes to lay its eggs. Some species of Snails also

have the double organs—a lung cavity and a gill cavity, which are used alternately or as required. In the case of those mollusks that live chiefly on land and breathe exclusively air, viz., the various Slugs, pond and land Snails, and the operculated Cyclostomi, &c., the respiratory cavity occupies the same position as in the aquatic and amphibian species, but the modification of its structure has now turned it into a true pulmonary chamber or lung.

There are several species of Crabs that inhabit the land, partly or exclusively, whose gill cavities are all more or less modified for breathing air. The gill cavity of the land Palm Crab (Birgus-latro) is divided into two, the upper one, a true lung, never containing anything but air, which there comes into contact with both veins and arteries. The pond snail (Limnea) proves, in its own development, the modification of gill cavity into lung, because when it is first hatched, for a time it breathes only water, but afterwards it changes to air breathing exclusively. Prof. Forel, however, found Limneans in 130 fathoms of water in Lake Geneva, that, of course, breathed only water all their lives, but on being brought to the surface they filled their respiratory cavities with air, and discarded the water breathing. This shows how nearly alike water breathing and air breathing may be after all. At any rate, it proves how easily air breathing may succeed water breathing by the same apparatus—on the principle of a greater including a less, since if the apparatus could get sufficient free oxygen from the water, which contains but little, it need not be astonishing that it could get it from air which contains much.

There are several genera of fishes belonging to several different families, that possess the double breathing apparatus. These fish are called *Labyrinthici*, a term suggested by the peculiarity of their gill cavities. These cavities are very large, and are only partly filled by the gills, the rest of the space being occupied by folds and doublings of the mucous membrane more or less complicated. These folds increase the surface of membrane that is exposed to the action of the air which is admitted to the cavity, and which there, by endosmose, oxydizes the blood on the opposite side of the membrane. It is plain how fishes provided with this air-breathing apparatus might be able to live out of water, and so we find several kinds that spend much of their time on land, and some make long journeys across the country, using the spines on their fins and gill covers as organs of locomotion. There are two genera of of the Goby family notable for their partiality to land life. It is a matter of conjecture not merely, but of plain certainty, that if left to themselves for some ages the descendants of the Gobies would be represented by animals having tolerable sort of feet attached to their gill covers and side fins, and well developed lungs at the sides of the neck. But the

competition between different breathing apparatus has awarded the preference to another locality as the best place for a lung. That locality is the interior cavity of the body. It is essential that every cell that goes to help make up the various tissues of the body should respire, but it is impossible in a large body that every cell should have direct communication with the air. The air must be conveyed at second hand to a great majority of them. The blood, in every animal that has blood, acts as the medium of this conveyance. Any specially differentiated aerating apparatus must and does, therefore, have reference chiefly to getting air into contact with the blood. As the blood vessels lie in the body cavity between the intestinal tube and the outside skin layer, the air must reach them by passing through either the outside skin or the membranes of the stomach. The gills are a section of the former, the internal lungs a section of the latter. There can be no doubt that the air bladder of all fishes that possess it, contributes more or less toward the aeration of the blood, whatever other service it may perform in regulating the specific gravity of the body. It may be admitted that in those fishes in which there is no air duct connecting the bladder with the esophagus, the bladder receiving its air by osmosis, the service of aeration by the bladder is comparatively inconsiderable. But wherever the bladder is connected with the gullet by an air duct, its respiratory function is increased. Almost all the more active fishes get part of their respiration through this air bladder, and they are therefore obliged to have recourse to the surface of the water in order to renew the air. If they are prevented from doing this by ice—or if a net be stretched across an aquarium just under the surface of the water so as to prevent the fish from reaching the air, they will die of suffocation. According to Semper, if the air duct to the bladder of certain Brazilian fishes—viz., the *Sudis-gigas*, *Erythrinus taeniatus* and *Erythrinus Braziliensis*—be ligatured so as to prevent the inhalation of air, suffocation is the result. (Semper 190.) The gills are insufficient for the oxidation of all the blood and are reinforced by the bladder, which is, therefore, to these fish a true lung and an essential organ of respiration. The Ganoid fishes, including the Amia, Sturgeon, Gar-pike and Polypterus of Africa, all possess the bladder connected with the throat by a tube.

In some of them the bladder is double, and in some, especially the Polypterus, it has a cellular or divided structure internally composed of folds of the mucous membrane, and giving a greater surface of exposure to the air.

There is no air bladder in the Blennies, Flatfishes, Sand-eels, Loricarini, Symbranchii, and some members of other families. But all that have the bladder have also in embryo life a duct leading to it from the intes-

tine. This indicates the origin of the bladder to be, as Huxley states it, a mere "diverticulum" of the intestine. In the Herring, Carp, &c., as well as the Ganoids, this tube is useful and persistent through life, while in the Cod and Perch, the tube becomes obliterated and the bladder remains a closed sac. There are several indications of retrograde development in certain particulars in some of the Teleostean fishes and this appears to be one.

The Dipneusta, including the Lepidosiren and Ceratodus, constitute the connecting link between the Ganoid fishes and the Amphibians. Like the Ganoids below them they are in one sense Amphibians. In them the swim bladder is a double organ and cellular and connects with the throat by a tube for breathing. It is the full equivalent of the lung. Yet the animals retain the gills, and both organs are used. In some of the Amphibians the gills only are used in the youthful stage and the lungs only in the adult stage. In all the vertebrates above the Amphibians the gills are developed in the embryo stage, and the blood vessels run to them as if to receive their respiration there as of old, but the lungs are also developed in the embryo, and before birth the gill arches are turned to other use and after birth the lungs alone are depended on. It may be observed that in connection with the complete development of the swim bladder into lungs in the Lepidosiren, the nasal cavity is opened back into the throat so that air can get into the lung without the necessity of the mouth being opened, as the case is with other fishes.

It is to habit and use therefore that we must attribute the building up of the lungs or other breathing apparatus, as well as the specialization of the various parts of the system, limbs, &c., as pointed out above.

First his environment driving the aquatic animal to greater activity whereby his system undergoes greater exhaustion, he automatically offers a greater amount of the carbon of his wasted tissues to the chemism of oxygen. The animal learns by experience that the sensation of uneasiness caused by suffocation is relieved at the surface of the water. Accordingly he goes there and exposes himself to the action of the air, some of which reaches his gills and some his stomach. The oftener this is done the more active will the fish become, and conversely the more active he is the oftener will he repeat the habit. The oftener the habit is repeated the more specialized will the part become which is exposed to the chemical interchange between the two elements. The intimate and ultimate nature of what is called *habit* will be discussed further on. In the meantime we are learning that use and habit are the immediate potent factors in building up organisms and effecting the specialization of organs and parts, while disuse and inertion are negative factors permitting the subversion and gradual atrophy of parts once built up.

CHAPTER XXIV.

CHLOROPHYL.

Mention has been made of chlorophyl. This substance, like protoplasm, in general, is composed of oxygen, hydrogen, nitrogen and carbon, to which is added iron. Under the influence of sunlight it becomes green. In the lower cellular plants it appears to be diffused throughout the mass of the protoplasm of the cell, coloring it all more or less.

In the higher vascular plants, however, the chlorophyl protoplasm is separated from the rest; a differentiation has taken place, and the chlorophyl appears in the form of individually organized particles, or granules from 1-1000 to 5-1000 of a millimeter in diameter. These organisms grow under proper conditions of nourishment and solar stimulus, and at maturity reproduce and multiply by fission, each adult particle becoming two. These zoospores, under the influence of heat and light, move about in the cells of the leaves of the plant. At night, and

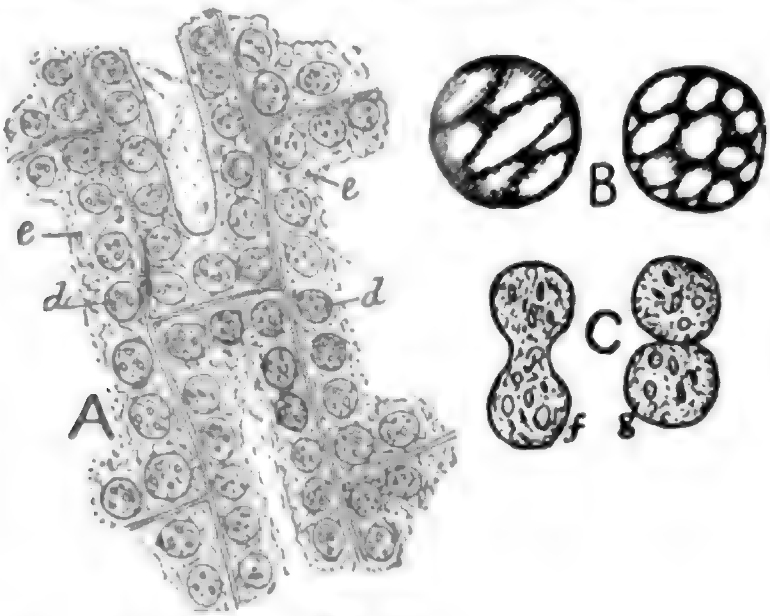


FIG. 90.

FIG. 90.—*Chlorophyl Cells.*
A.—Part of a green leaf.
d.—Chlorophyl cells containing *green* protoplasm and *granules* of *starch.*
e.—Protoplasm of the leaf cells.
B.—Old Chlorophyl cells.
C.—Chlorophyl cell in act of dividing, or reproduction.
f.—Beginning of the process. *g.*—Ending.

as the temperature decreases, they huddle together in the center of the cells, but in daylight, and under increasing temperature, move out toward the cell walls. Their color, when light is withdrawn, becomes pale and yellowish, and if the light is withdrawn too long the organism loses its power of growth and its substance is redissolved back into the mass protoplasm of the plant. Although the body of the chlorophyllian zoospore does not contain either potassium chlorate or potassium nitrate yet one of these bodies must be present in the sap of the plant in order that the functions of the chlorophyl may proceed properly. We are reminded of the extreme sensibility to light, shown by these

substances, in the practice of photography. As has been mentioned elsewhere, the peculiar function of chlorophyl is to extract the carbon from the carbonic acid of the air, retaining a portion for its own growth and renewal, and forming the rest into starch—which is composed of carbon, hydrogen and oxygen, but is destitute of nitrogen. Starch is to be regarded as the surplus store of carbon, above the immediate needs of the chlorophyl organism, and is something akin to surplus fat

Colorless Blood Corpuscles of Young Stag increasing by self-divison.

a—Original cells with kernel or nucleus.

The kernel first separates into two pieces and afterwards the protoplasm divides into two, each one taking one of the kernels with it, *b, c, d, e* being progressive stages in the process. (*After Frey.*)

f—Division complete.

The Colorless Corpuscles are formed in the colorless blood or lymph, and carried thence into the red blood, where their cell walls are broken up and their nuclei liberated to become the *red* corpuscles of the blood.

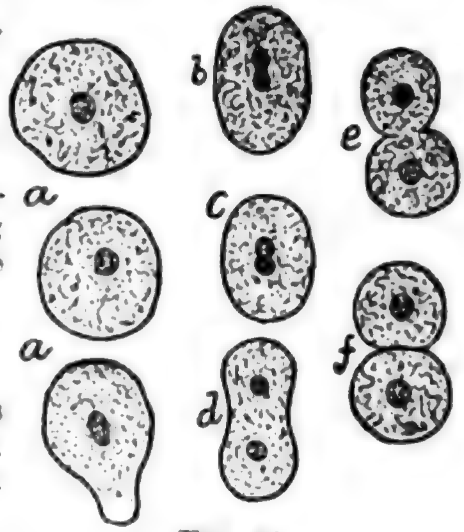


FIG. 91.

in an animal body. Exposed to the action of the juices of the plants, this starch is subjected to fermentation, converted into sugar and carried into the various tissues. Letourneau (Biology, p. 97) draws a parallel between the chlorophyl organisms and the hæmatoglobuline, or red globules, of the blood. These red globules are the active zoospores of the blood. They incessantly imbibe oxygen from the air, and constantly give it up to the other tissues of the body, receiving in exchange

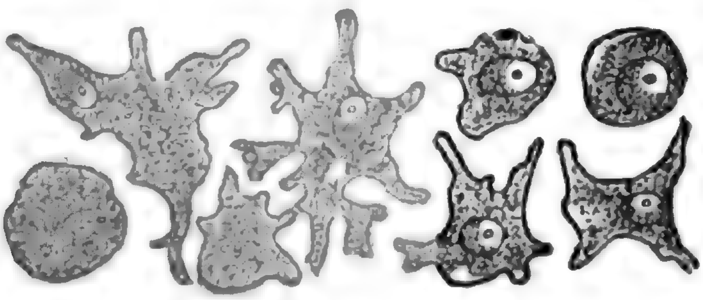


FIG. 92.

Eight Colorless Blood Corpuscles of the Naked Sea Snail Thetis much magnified (*Hæckel*). They move, absorb matter, both fluid and solid; eat in fact just like Amœbæ.

carbonic acid which is readily given up to the air in exchange for pure oxygen.

There is, indeed, a parallel between the chlorophyl zoospore and the red blood corpuscle, but it appears to me to be an inverted parallel, since the one is constantly undoing what the other does. The chlorophyl body conveys the carbon from the air to the cell of the plant and leaves it there. The red corpuscle loads up with oxygen from the air

and carries it into the inner parts of the body among the combustible cells built largely of carbon—like an incendiary carrying a torch into a shop full of shavings. All the iron in the blood is contained in the red corpuscles and this iron, no doubt, contributes very largely to the capacity of the corpuscles for carrying oxygen. For oxides of iron greedily absorb oxygen, which, however, they readily give up to organic substances. And the blood has much greater capacity for oxygen gas than the same quantity of mere water. The business of the red corpuscle then is to burn up the starch which the chlorophyl cell has gathered from the air.

The size of the red globules is from $\frac{6}{1000}$ to $\frac{9}{1000}$ of a mm. in the adult man. Their shape is disc-like with the sides depressed toward each other. These depressions partly disappear when the globule is charged with oxygen, the sides swelling out, but when the blood takes up carbonic acid they shrink. They are without nucleus, in which respect as well as in shape they resemble the chlorophyl zoospores.

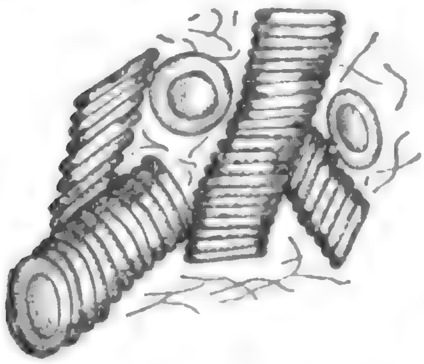


FIG. 93.

FIG. 93.

Red Corpuscles of Blood. They are disc-like, depressed in the middle, and tend at times to pile themselves together like dinner plates.

But they are unlike the chlorophyl in this respect that their functions do not directly depend on the light, but go on day and night. In the night, or in the continued absence of light, the chlorophyl ceases to decompose carbonic acid and to form starch. On the contrary, some of the carbon of its own tissues is absorbed by the oxygen of the air and carbonic acid is thus formed at its expense. Thus it was estimated that a certain square decimeter of green surface lost by consumption $\frac{214}{1000}$ of a gramme of the carbon of its tissues during twelve hours of darkness, while in a like period of light it gained $3\frac{418}{1000}$ grammes. The latter figure is named as the amount of the assimilation, but it is only the net assimilation. The daily expenditure must be much greater than the nightly, and the total assimilation much more than the amount named. The functions of chlorophyl are performed under the stimulus of all colors of light, but the yellow rays are the most energetic in such stimulation, and under their influence starch is formed most rapidly. The yellow rays, too, are much the most active in the differentiation of the chlorophyl from the rest of the protoplasm in the first place, and of developing in it the molecular structure that reflects the green rays. The upper surface of the green leaves is by far the most active in the decomposition of carbonic acid, for the reason that being ordinarily the most exposed to sunlight it contains the greater number of the chlorophyl zoospores. If

a leaf be artificially restrained in an inverted position it will twist its stem in an apparent effort to right itself and expose the right side to the light. But if prevented from turning, in the course of time the carbonic action may cease in some leaves entirely.

The rays below the visible spectrum—that is, the exclusively heat rays—have nothing to do with the chlorophyl function of starch making. A proper temperature is essential, but no amount of dark heat alone will produce the effect. To get a conception of the mechanical process involved here we must consider the physical difference between a ray of dark heat and a ray of yellow light. As explained in Chap. 40, they are both waves of the same material medium, and both advance with the same rapidity. But the yellow waves are $\frac{2}{100\,000}$ of an inch in length, and strike an opposing object at the rate of 543 trillions in a second, while the dark rays are composed of waves several times longer and several times fewer per second. What is said in Chapters 39 and 40 of the fundamental tone or note of vibrating bodies will help us to comprehend how waves of a certain particular swing or vibration are essential to the setting up a vibration in any ponderable body. Now, knowing by experiment that the ether waves of a particular time and movement are able to set up such a vibration in the mineral gas, carbonic acid, that the affinity of its two elements for each other is neutralized, and at the same time to set up such an activity in the organized chlorophyl zoospore that new combinations between the elements of the mineral and those of the organism are possible, we conclude that the fundamental note in both bodies has been vibrated and that they are tuned in unison with each other. But more than that, the organism, at least, has been brought into tune by the action of the ethereal radiant energy. If we consider the exceedingly fickle and mobile constitution of every compound containing nitrogen, it will appear how easily the protoplasmic compound may be influenced and molecularly rearranged. It is not necessary to suppose that the action set up in the organism by the vibrating medium is a vibration of its atoms in the time or at the rate of the original vibrating medium. No organic body could stand such a rate of motion without disintegration and destruction. But there is a rearrangement of the molecules of the plastic organism by the vibratory force, and, consequently, a new system of intermolecular spacing. It is the form of the intermolecular spaces that gives the fundamental note, because it is through these spaces that the movement of the vibrating ether is propagated, and it depends on the form of these spaces what the length of the waves shall be that get through them. Thus the fundamental tone of a body played upon by light as well as the tone of sound in a resonator, depends on the form of the internal spaces into which the vibration is introduced, and the

vibration is the movement of the ether within the intermolecular spaces. As we shall see, both mineral and organic bodies are subject to this rearrangement of molecules and of intermolecular spaces by the action of ether waves of one length or another. But we may reasonably expect that the effects are more rapid and effectual in the case of the plastic organic bodies, and observed facts bear out the expectation.

This will be better understood after reading Chapters 39 and 40.

We must distinguish between the function of the chlorophyl bodies and the growth of the roots, deposit of nourishment and repair in the woody stems of plants, also the growth of the flowers and fruits. All these latter processes consume oxygen and form carbonic acid, entirely reversing the action of the chlorophyl bodies. In this, they imitate animal life, and the growth of the fungi. Among the lower cellular plants —the Algæ, &c.—the function of gathering the carbon from the air appertains to all the parts of the plant alike, and the surplus starch is not removed but remains near among the cells where made. But in the higher plants the differentiation of the chlorophyl organisms is accompanied by the differentiation of places of deposit for the surplus products of their action, and of machinery for the removal and deposition of these products and of their erection into various tissues and organs—all which operations require work or are work, and are accompanied by the consumption of carbon and the exhalation of carbonic acid. Night and day, during growth, this exhalation from these parts goes on. In the night it goes on from the green chlorophyl bodies themselves, because during that time the tissues of these organisms are being repaired, and the matters wasted by daily work are being replaced.

Chlorophyl has been spoken of all along as *green.* But there is also red chlorophyl. This occurs in the red protococcus, a minute alga which gives color to the waters of the Red Sea and to the red snow of Greenland.

There is also yellow chlorophyl and blue chlorophyl—called, respectively, Xanthophyl and Cyanophyl. Chlorophyl has been separated and shown to be made up of these two, as green color generally can be formed by the combination of yellow and blue. It is questionable to what extent these yellow and blue protoplasms may be concerned separately in the formation of starch. The probability, it seems to me, is that the first action of light upon the mass protoplasm of the young growing plant is the formation of the yellow colored bodies, and that they are possessed of limited power in the absorption of carbon, subsequently they are reinforced by the later development under stronger light of the blue matter, the mixture with which produces the green color. The chlorophyl is reduced to its yellow skeleton by the withdrawal of sunlight, or the proper amount of moisture, or the proper amount of heat,

as in the autumnal change in deciduous leaves. It is well known that plants will germinate in the dark, and will continue to grow until the starch, deposited in the seed, is used up, after which if they receive some light they form the yellow coloring matter, and continue to grow in a sickly, ineffectual way, but finally take on the healthy green when exposed to full light. "A writer mentions a forest upon which the sun had not shown for twenty days. The leaves, during this period, were expanded to their full size, but were almost white. One forenoon the sun began to shine in full brightness; the color of the forest absolutely changed so fast that we could perceive its progress. By the middle of the afternoon the whole of this extensive forest, many miles in length, presented its usual summer dress." *

Diffused light will not start the starch making action of the chlorophyl cells of water plants, but will keep it up after it has been started, by direct radiation. † As mentioned, the action stops at night. And to prove how completely it is due to the action of light, observation has shown that in water-plants it is checked by a shadow from a passing cloud.

The colors of flowers of course depend on the action of light. In many cases these colors change from one tint to another, under such action. Some are white at first, and afterwards yellow or purple. Some change from one day to the next, others during a day. One of the Rose Mallows opens out white in the morning and becomes red during the day.

By artificially preventing the action of the light, the change of color in flowers can be prevented in some cases. The tints of fruits are also dependent on the action of light, and in this case the molecular change goes below the surface, for the odor and taste of fruit alters greatly under the influence of light.

Certain mechanical movements of plants are due to the action of light. All plants seek to expose themselves to the light. The action of the Sunflower in twisting about to receive the rays of the sun, is familiar. Payer experimented with the young stems of common garden cresses, grown on damp cotton in the dark. The stems curve quickly toward the side in which light is admitted, the top of the stem, being the most flexible, turning first, and the lower part afterwards. He also sowed turnips, and while the plants were small exposed them to the divers rays of the solar spectrum. They all bowed toward the blue—from both sides of it, showing that the blue rays influence this action more than the others.

Darwin concluded that the light affected the action of twining plants. In one case a growing twining plant in a window was observed to grow around an entire turn of its spiral twist in five hours and twenty min-

* Youman's Chem., 241. † Papillon, 105.

utes, but the half of the turn growing *from* the light required nearly four and a half hours, while the other half—growing towards the light—was accomplished in less than one hour.

Everyone has observed that solitary trees are more bushy, and put out branches lower down their stocks than those growing in a forest, because the light has better access to their lower parts.

It is a curious and significant fact that certain of the lower animal organisms possess chlorophyl.

Semper raises the question whether these chlorophyl bodies may not be separate organisms living with the little animals as commensals or messmates, and yet not having anything to do with the vital economy of the animal. It has been shown that in some, at least, of the animal organisms—the *vortex viridis*, for example—the chlorophyl cells increase and divide spontaneously, like other animal cells, zoospores, &c.

If the chlorophyl cells act in the animal organism as they do in the vegetable, they not only support themselves, but manufacture a large surplus of starch which they do not need. It is extremely unlikely, indeed impossible, that the animal organism in contact with this starch, in fact having it mingled with its own tissues, should not absorb and make use of it. It is evidently one of those cases of reciprocation of offices between mutually dependent organisms, which constitutes all vegetable and animal organization above that of the single celled organism. In this case, probably the chlorophyl cell is formed from the protoplasm of the animal by the action of light, just as it is formed from the protoplasm of the plant. It then proceeds to digest carbonic acid and form starch, the surplus of which goes to the support of its animal host—a clear case of a mutually profitable reciprocity. The animal here is so close to the vegetable kingdom, that in fact both kingdoms are represented in the single organism. Throughout the animal kingdom there is the same dependence on the chlorophyl cell for its surplus products, and without them the animal kingdom could never have come into existence.

But the development of locomotive organs in the animal, making it possible for him to go to the vegetable for his food, has rid him of the necessity of retaining the chlorophyl cell in his own organization, and so all animals, except some of the very lowest, have lost the chlorophyllian function. In a primitive state of society, each family ground its grist at home, but a division of labor enabled them to go to mill.

Semper gives the following list of animals possessing *chlorophyl, xanthophyl*, &c.
Protozoa.—Euglena viridis.
Stentor viridis.
Almost all Radiolaria. (Two families excepted.)
Spongilla viridis.
Cœlenterata.—Hydra viridis.
Annuloida. —Vortex viridis, a Turbellarian worm.

Also the decomposition of carbonic acid has been proved to be a function of the green Turbellarian worm, *Convoluta Schultzii.*

CHAPTER XXV.

PARASITISM AND SOCIAL RECIPROCITY.

The term Parasite, made up of two Greek words, *Para*, alongside, and *Sitos*, food, may be freely translated to mean one who partakes of the food of another. The Tapeworm is a most complete example of a parasite in this literal and original sense, because he intrudes himself into the "very kitchen" of his host and helps himself to the victuals as fast as they are prepared, often not even leaving enough to keep his host from starvation. But the use of the term has been extended to include those who do not eat *with* the host exactly but eat *him*, or at least such parts of him as can be spared without fatal results, and also still others that neither eat their host nor his food but manage to get a good living out of the refuse of his food, the excreta of wasted tissues, and the accidental dirt that sticks to him.

A host is necessary to a parasite, and in a great many instances a parasite is necessary to the host. The relationships of these two, the extent to which they reach and the mutual inter-dependence which these relationships have established between the various mundane organisms, are of much greater consequence than one might suppose. To the extent that a host becomes dependent upon the parasite it may be said to be itself parasitical. And if we charge parasitism upon every organism that avails itself of the labors of others, we shall find such a mutual dependence running through the whole animal kindgdom and crossing over into the vegetable kingdom, that we will have to set down all the animals and a large part of the vegetables in the list of parasites. This mutual dependence grades all the way from that which is essential to existence itself, to that in which the mutual offices are simply helpful, but which could be got along without. It is evident that the development of parasitism must have begun at the last end of this grade, the partial end, and the beginning must have been made in the vegetable kingdom. The first organisms got their living directly from the mineral kingdom, and when any of them began to live to any extent upon their fellow organisms it was not a vital necessity, but only a convenience to do so.

But as their living upon others rendered it unnecessary to use certain of their own powers that had been developed in their struggle with the mineral kingdom, these powers dwindled with disuse and became aborted, while others better adapting them to profit by their new relationships became developed. So that to-day but very few vegetables exist that would remain anything like what they are if transplanted to such an original mineral soil, devoid of all organic matter, as gave sustenance

to the protophyte alga of Laurentian days. Plants now live largely on the remains of their dead ancestors, and finding so much work done by those ancestors in subduing the mineral soil of the earth and impregnating it with organized materials more easy of assimilation by the tissues of plants, those now living are endowed with a less vigorous and rugged constitution, that is, have lost certain functions possessed by their ancestors. In most cases they have gained other functions of a higher order than those lost, and with them a new and more complicated morphology. This leads to the observation that while the organism struggles directly with the rugged and incult forces of nature, its own development must be limited and its functions must remain simple in correspondence with the simplicity of the forces of the environment. But the reactions of the organism change the conditions of the environment not only by work done, but both in the case of plants and animals, but particularly plants, their own remains contribute to place the environment under different conditions at the end of every generation, so that succeeding generations are by their means placed under new stimuli, and, getting the benefit of the lives of those gone before, are able to attain a different development. The roughest work having been done they do not have it still to do.

Such language as this must not mislead us into a conception of organisms doing something; the real fact being that the forces of the environment having, by the creation and destruction of a generation of organisms and the addition of their reactions, and the reaction of their remains to the environment, changed *it* by so much, these forces are enabled to produce a new generation different from the first, and having functions fitted for a new state of things. As a bricklayer may lay an upper course only after he has laid a lower one.

The very same principles govern the action of contemporaneous organisms upon one another. A certain organism requires to have certain work done for it. If this essential work can be done by another organism (or, rather, *through* it), organism number one may rest from that labor or may do something else, but if he does, his ability to perform that labor will be diminished. He may acquire some other ability in its place, or in some way render an equivalent or partial compensation for the work thus done for him. Thus man puts upon a horse a great deal of work he would otherwise have to do himself, but he returns some of his own work in furnishing the horse a sheltered stall and a secure supply of food. Man's relations with his domestic animals are akin to a mutual parasitism with the inevitable effects of parasitism in reducing some of the personal functions. Our ape-like ancestors were endowed with a hairy covering which, no doubt, sufficed to preserve a sufficient warmth for ordinary comfort. But a luxurious habit of sup-

plementing this natural coat with the clothing of his fellow animals from whatever motive or whim at first, came later to be desirable and at last to be necessary to his comfort, and in all but torrid countries essential to his existence, since by the disuse of his own natural clothing he has lost almost the whole of it. In personal prowess, strength of limb, claw and jaw, the man of flocks and herds is no match for a gorilla. The domestic animals have likewise largely lost the power of self help by having so long been wards, and it would go hard with many of them if they were left to their own resources to get their living. They have all been carefully selected and improved by man in the qualities useful to him, but those useful to themselves in a state of nature have been largely lost.

The parasitic habit of the Cuckoo of laying her eggs always in the nest of another bird, has probably reacted on the tribe in destroying their faculty for building nests. The Molothra, a variety of the Troopial, is another bird that has this habit.

The English Cuckoo is described as a "discontented, ill-conditioned, passionate, in short, decidedly unamiable bird." They are unsociable, and migrate alone. The males predominate, being five times as numerous as the females, and, according to some authors, more than that. They are very greedy, selfish, and of a gluttonous appetite. The males and females do not pair or mate, in the sense of keeping company, though in the breeding season the males are passionate. The female when adult cannot be distinguished externally from the male. The reproductive organs of both sexes are very small for the size of the bird. The parturition is sluggish, intervals of six or eight days intervening between the laying of the eggs. The eggs are small and are deposited in the nests of insectivorous birds, usually one in each foster nest, but occasionally two. After the young cuckoo is hatched it shows the greedy and selfish disposition of its race by often ousting its foster brothers and sisters from the nest, and monopolizing all the food, and it grows remarkably fast. There is occasional reversion of the English Cuckoo to "ancestral habits, even, in some cases, to apparent affection for the young."

The American Cuckoo is only occasionally parasitic, but is usually not so careful of and interested in its young as other birds. To work for another begets affection for him.

It is evident that the parasitic habit is an acquired one, the ancestors of the Cuckoo having, at one time, had the maternal instincts of other birds. The shirking of the maternal function of building the nest, then of caring for the young, &c., undoubtedly was the cause of the decline of the maternal instincts in the race, the preponderance of the males, their greedy and selfish disposition, the similarity between the sexes,

the reduction of the reproductive organs, and of the eggs, the sluggish parturition, the absence of mating, the rapid growth of the young, and, in general, the development of individualistic and egoistic qualities, and the suppression of the altruistic, the breaking up of the family and the loosening of all the bonds of the society.

The parasitic Bees mentioned by Darwin (Sel. of species, 194) are another example. There are many varieties of them that deposit their eggs in the nests of other Bees, and they thus escape the work of collecting pollen to store the nests. But in shirking out of this work they have not only lost the art of performing it but have even lost the apparatus necessary to do it, and must depend on other bees to rear their young.

The history of the slave-making ants, related by Cuvier and Darwin, is to the same effect. Some of the tribes are fierce and enterprising, making long journeys to the nests of others to carry off their pupæ. These they rear in their own nests to become their household servants, where they are compelled to build and arrange the nest and care for the young. In other cases the slaves are likewise field servants and soldiers and assist their masters in defending the nest or in carrying the larvæ and pupæ out of danger. But the most extreme case is that of the *Formica Polyerges rufescens.* Ants generally are divided into three sexes—masculine, feminine and *neuter.* The neuters, like the workers among the bees, are females with undeveloped and functionless ovaries. And these neuters, in some varieties, do all the work, the males and females doing nothing after the eggs are laid. Cuvier even says the neuters drive out the others in some cases. But in the tribe above mentioned, in which the males and females have shirked out of all work and even forgotten how to do it, the neuters, too, have adopted shiftless habits; for, having taken up the practice of making slaves, they have put all the work upon them. The neuters are very fierce and enterprising in capturing the larvæ and pupæ of the *Formica fusca*, which they rear in their nests into neuter slaves. But they do nothing else whatever. These slaves not only build and open and close the nests, but they feed their masters, both old young, who would all starve to death before they would feed themselves.

To observe the extreme effects of parasitism, we must go to such animals as the *Sacculina* and the *Entoconcha mirabilis.* The sacculina is a crustacean parasite on a brother crustacean, the Hermit Crab. The young sacculina is hatched from an egg, and is an oval body possessing three pairs of legs and usually a single eye in the middle of the head, but no mouth or digestive system. It is able by means of its limbs to swim. The animal in this stage is called a nauplius, and it closely resembles the nauplius of those other curious crustaceans, the Barnacles

and the water flea, Cypris. Its second stage is called the pupa stage. Here it is much like a corresponding stage in the Cypris, while the Barnacle at that stage shows signs of divergence. In the pupa state it is invested with a shell which is a bivalve with a hinge along the axis of the back. In this it resembles both the cypris and the barnacle pupa. Next the two front limbs become modified into feelers, or organs of attachment, and the four hinder limbs are cast off and are succeeded by six pairs of forked swimming feet. In these two particulars it imitates the development of the Barnacle. But here they diverge. With the help of his swimming feet and under the direction of his one eye, he hunts a "host" and a square meal. This host is usually a hermit crab. Into the intestines and among the liver tubes of this "host" the feelers of the sacculina feel their way by means of numerous root-like ramifying appendages, which are developed on them and through which the digested nutriment is conveyed into the tissues of the sacculina. The latter now having no further use for swimming organs nor eye nor semblance of head, these are all aborted, and the parasite remains nothing but a sac, shaped like a sausage or a discoidal bag, or perhaps like an unsymmetrical lump. It receives and expels water through a wide orifice by which its tissues are oxidized, a process of quasi respiration; but beside this it has no other function than to mature the eggs for the next generation.

When this function is completed the sac drops off, leaving its root-like feelers still in the host where they continue to live for some time totally functionless, their occupation entirely gone. This animal never has a stomach and never digests any food, but absorbing it from the tissues or digestive organs of the host, by endosmose, it does nothing but assimilate it in its own tissues. Its youth is more noble than its old age, for in youth it possesses at least two sense organs, sight and touch; it has the power of locomotion and some power of nervous co-ordination, a will and choice. But it loses all these at maturity, and in old age it has no more sense or sensibility than a turnip.

The history of the Sacculina was observed to run parallel at first with that of the Barnacle in many respects. The Barnacle, however, has at first a mouth and stomach, and does some vigorous feeding in the Nauplius stage. Later, however, in the Pupa stage, this mouth is closed, and it does not feed during the time occupied in finding a suitable place of attachment, and in this stage it is very like the pupa of sacculina, having, however, two eyes instead of one. But its subsequent life is altogether different, for fixing itself to a log or ship, or some other inanimate object, it has to feed itself and digest its own food. So its mouth is reopened, and stomach put in running order. Its fore legs, which became feelers, as in the Sacculina, now become prehensile organs to

make its attachment to the log, the two eyes are degenerated into a single minute eye spot, and the swimming legs now act to paddle the current, with what food it may contain, toward the mouth. Both these animals show the degradation brought about by the disuse of organs. They are both related to the Cypris, and other branches of the very ancient Ostracoid family, some of whose members we found away back in Silurian times. Their different degrees of degradation are brought about by different degrees of disuse—the old Barnacle being willing to earn his living at a sedentary employment, while the Sacculina is unwilling and, in fact, now unable to even digest its food, much less to work for it.

There is a large number of Crustaceans, some of them related to the Sacculina, that lead such a life of parasitism as it does. A notable case is the Lernean, one of the numerous tribe of fish-lice. It is at first a six-legged Nauplius with a single eye, and lively habits, but fastening upon the gill of a fish it settles down to parasitism and loses its shape, its limbs and all its activities and functions, except to bear and mature the eggs for the next generation. There are also many tribes that imitate the life of the Barnacle, beginning as lively and active animals, with a well-developed nervous system, locomotive and sense organs, they spend their young days in seeing the world, then settle down upon some fixed object, lose their activity and everything superfluous in the way of organs or senses, and merely vegetate during the rest of their lives. The Balani, or Sea Acorns, live such a life. They are Crustaceans and related to the Barnacles. The Ascidians, or Sea Squirts, are another and a remarkable example (see Figs. 58 and 59). For the free swimming tadpole-like larva possesses, along with other advanced marks of development, a veritable notochord or rudiment of a backbone, such as all vertebrate embryos develop at first. In the sedentary state which follows this free life this notochord is abolished and with it a large part of the nervous system, locomotive organ, &c., proving the sea squirt to be a degenerate family from a stock possessing a notochord and preserving their activity to the end of their days—like our modern Amphioxus. To this ancient stock, through which all vertebrates must trace their pedigree, Hæckel has given the name Chordonia, or chorda animals.

This mode of life in which the youth is locomotive, active and sensitive, and the old age fixed, motionless and stolid, with a greater or less abortion and degradation of organs and senses, is extremely common amongst the mollusks and the plant animals, and is the rule among the plants themselves, seeds generally possessing more or less ability to be moved; some having organs specially fitted to aid in their movableness, as the wings of maple seed and the down of thistles and cottonwood, while others, as the spores of the protococcus, alga, &c., have

vibratile cilia by which they propel themselves through the water after the manner of an animal.

The case of the molluscous parasite *Entoconcha Mirabilis*, is even more remarkable than the crustacean parasites named. The larva of this mollusk has an oval shell with an operculum, or cover, to fit the mouth; it has a "velum," or sail, or organ for swimming such as possessed by many similar larva of the univalve mollusks; it has a gill cavity and intestines, an auditory organ and a correlating nerve ganglion, and, in short, is equipped exactly to all appearance like the larvæ of those univalve mollusks that remain free all their lives. But this one becomes a parasite in a Holothurian (sea-slug), and as he matures here he loses everything—his shell and cover, his swimming organ, his ear and his piece of brain, and, in short, he is converted into a mere parasitic pouch, saving nothing but the hermaphrodite male and female glands and rearing the embryos of the next generation.

The same food is not appropriate for all the stages of the life of an animal, as a general rule. In the case of mammals, the young for a year or two live on milk and later become adapted to their adult food of grass, grain, fruit, meat, &c. In the case of the young parasites, in order to obtain the progressive food supply, the animal must migrate, since its parents from their extremely shiftless habits are very poor providers. It is this necessity of going to the food, since the food cannot be brought to them, that develops the activity and enterprise of the young of parasites and *sedentaries*, as such animals as the Barnacle may be called, while the infants of active parents are relatively helpless, as in the case of mammals, especially the primates. This necessity is further illustrated in the case of the entoparasites or those living within the body of the host. The Trichina Spiralis, a nematode worm, gains entrance into the body of an animal—a pig, for instance—by being eaten. In the stomach of the pig the Trichinæ are set free from the muscle in which they had been confined as the muscle is being disintegrated in the process of digestion. In the space of three days the Trichinæ grow to maturity and become sexual, the females being more numerous than the males. They possess a mouth and intestine and sexual glands. The females then lay a prodigious number of eggs, from each of which is hatched a microscopic young Trichina. These bore through the walls of the stomach or intestines and find their way to the muscles of their host, where they take up their lodgings, each one coiled up in a minute cavity or cyst formed between the fibres of the muscle. There their journey and their activities cease. They cannot lay their eggs in the muscle, neither can they go back to the stomach they came from to finish their growth and lay their eggs there. They may remain alive ten years where they are, but will be entirely inactive until the muscle containing

them is introduced into another stomach—a man's, for example, by being eaten *raw* (cooking kills them)—when the operation is repeated. When they are too numerous they produce disease, often fatal. "Leuckart counted 700,000 trichinæ in a pound of the flesh of a man, and Zeuker speaks of even five millions in a similar quantity of human flesh."* Trichinæ of one variety or another may inhabit any warm-blooded animal. (In some, however, they do not bore into the muscles and become encysted, but pass out with the feces, and by becoming attached to some article of food are taken into another stomach and finish their development.) The mouse harbors one which gets into a cat when the cat eats the mouse. In the stomach of the cat it deposits its young, which pass back to a mouse by becoming attached to some of its food. It bores into the muscles of the mouse and is there encysted ready to be eaten by another cat. Another parasite passes its life between a mouse and a meal worm. The meal worm is the larva of the *Tenebrio Molitor*, a coleopterous insect. It eats the feces of the mouse and the eggs of the nematode parasite, which may chance to be enclosed therein. These eggs hatch in the meal worm and bore through the intestine into the layers of fat that surround it, and remain there while the meal worm goes through his metamorphoses into the insect, which is finally gobbled up by a mouse, in whose stomach the parasite lays its eggs, and the cycle is complete. (Van Beneden, 247.)

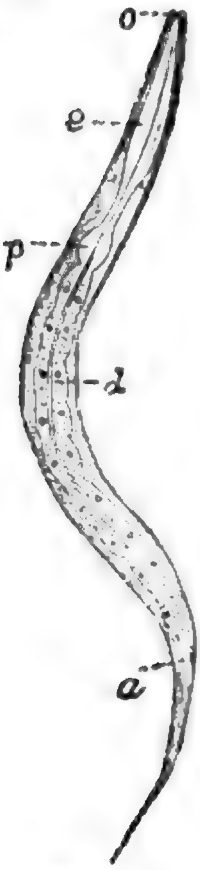


FIG. 94.

FIG. 94.—*Young Nematode Worm.*

A single intestine from one end to the other.

o—Mouth.
e—Widening which may be called an esophagus.
p—Pharynx.
d—Middle intestine.
a—Anus.

The Cestodes, or flat ribbon worms, differ from the Nematodes, round worms or thread worms, notably in this: that while the individuals of the Nematodes are always separate and independent from each other, the Cestode individuals remain attached to each other and to the mother that gave them birth. What is commonly called a tapeworm, consisting of a head and a great number of segments linked one after the other, is, in reality, a colony, the head being a complete animal and giving birth to each segment, one after another. These segments grow and in each one a great quantity of eggs are formed. The segment at the extremity opposite the head is the oldest and comes to maturity first. When mature it is detached and escapes from the stomach of the host in the feces. It is then nothing but a bag of eggs. The sarcode,

* Van Beneden, Parasites, 245.

or contractile skin of this bag, has no other function than to hold these eggs, and when it is eaten, or when it breaks up, as it commonly does upon exposure to the air, the eggs escape and are scattered upon the grass or in water, or are liberated in the stomach of a host. In any event they must get into a stomach again in order to continue their existence. And they may reach the stomachs of cattle, rabbits, sheep, &c., by being swallowed with the grass. A pig may get them from various sources, and man may get them from water into which they have been washed or discharged. In the stomach the egg, which is always enclosed in a strong and nearly impenetrable shell, is hatched, or at least liberated from the shell, the latter being dissolved or digested by the gastric juice, or otherwise, and the worm thus liberated starts to bore through the walls of the intestines and the tissues till it reaches a proper shelter in the cavity of a muscle or other organ, where it remains till the organ is eaten and they are introduced a second time into a stomach. Then, being liberated from the tissue that they are enclosed in, they attach themselves to the coat of the stomach and begin to grow one segment after another of the sarcode bags described above, in which the eggs are formed and encysted in their strong shell. It is necessary to carefully distinguish between the *eggs*, as they are when thrown off in the feces of an animal with a tapeworm in the stomach, and the *cysticercus*, which is the name given to the animal after it has bored from the stomach into a muscle and become encysted there.

The egg always produces the cysticercus before it can grow into a tapeworm. The formation of the cysticerci is often attended by disease when they are numerous. In the pig the disease is called the measles. In the sheep the disease called the "gid" is caused by the embryos of teniæ encysted in the brain. In man the presence of these cysticerci in the brain has caused mental derangement. But in all cases where the cysticerci get into the stomach after having been developed and embedded in muscle or other tissue, the tapeworm is the result. There are many different varieties of these teniæ, depending on the difference in the animals they frequent. The one that forms its segments and eggs in the stomach of man, and its cysticerci in the muscles of the pig is the *Tænia Solium.* The *Tænia Serrata* rotates through the stomach of dog or wolf and the muscles of rabbit. The *Tænia Medio-canellata* uses the stomach of man and the muscles, lungs, &c., of beef cattle, and has been confounded with the T. Solium, which it resembles. The one which lodges in the brain of the sheep and develops into a tænia in the stomach of the dog or wolf is called the *Cœnurus*, a name given before its nature was fully known. There are many others of which Van Beneden has given ample account.

From what was said in last chapter it appears that the relationship of

the Chlorophyl organism to its plant (or animal) is one of mutual dependence and helpfulness. The cell of the plant is the shelter, bedroom and workshop of the active Chlorophyl body which amply pays for its lodging in *starch*. There is another party belonging to this combination—*one Diastase*—a ferment and an organism, which will be described further on, which is an equally valuable member of the firm and which the plant could not get along without, since it takes the insoluble starch and makes it into sugar. These mutually cooperative organisms of the vegetable have their counterparts in every animal, which is, indeed, after all only a locomotive vegetable. The different sorts of cells which compose the animal body may be regarded as a cooperative community of separate organisms, each living its own life and in some way helping the rest, yet dependent upon the rest for its existence and preservation. In this partnership there are blood corpuscles, the cells composing the various tissues, muscle, bone, nerve, skin, &c., and a dozen different kinds of *ferments* which inhabit special parts called glands. The relations and mutual adaptations of these several organisms toward each other have come about through their habit of living together and acting upon each other through an infinite series of generations. As long as they are properly nourished and not interfered with by strange and adventitious organisms from the outside, the body which they compose remains in a healthy and normal condition. But the nourishment that is good for the cells and ferments that belong to the body is also good for the many strange organisms that infest the air, the water and the ground, and are always ready to get a foothold in the body and compete with the normal household for a share. They not only do this but they compete with one another. One species of parasite or, in some cases, even one individual, may be an antidote against all others, keeping the others away by some sort of competition, as rats keep away mice, or as vaccine keeps off small-pox.

There are many species of the Bopyridæ, a Crustacean family, that is parasitic on other Crustaceans, as crabs, or tailed Crustaceans, living in their branchial or gill cavities. But the first comer that establishes himself in the cavity on one side is a bar to the intrusion of any more either in that side *or in the other* (Semper). This is singular, but is proved by many examples. Why is this? One theory is that the first parasite exhausts the peculiar food necessary for their support so there is not enough for the second. A second is that the first parasite occupies the avenues of approach to the food supply in the host, so that while the food is there it is inaccessible to a new comer, as Kentucky Blue-grass will root out sand-burrs, not by exhausting the soil but by occupying its whole surface and cutting off access to it. I suggest a third, which is that the action of the first parasite changes the nature of the secre-

tions of the host and so alters the intimate character and constitution of the tissues themselves or causes fermentation of the blood, that a new life and unnatural energy are infused into the cells composing them, by which they consume all the nutriment appropriate to the growth of the parasite, and so exclude it. We are to remember that every tissue cell of the body is a separate animal in precisely the same sense in which a germ or spore of vaccine or small-pox is, or even a tape worm or a saculina, the only difference consisting in the degree of degradation to which they have severally come by reason of the disuse of functions. The competition then comes between the normal tissue cell stimulated to preternatural energy and the adventitious parasitic cell. During its season of stimulated activity the parasite is unable to gain a footing. This season of the repellant energy of the tissue cell is of a definite duration, after which the cell relapses to its original mode of unstimulated life. As against small-pox it is said to last seven years, usually, but is good against measles for a whole lifetime.

The fact that we "outgrow" tendencies to various certain sorts of disease appears to countenance this theory, for this "outgrowing" can be nothing more than such change in the constitution of the cells of the body as to give them a more pronounced individuality and aggressive self-assertion, consolidation of texture and vigor of vitality, by which they are able to draw for their own support, to the exclusion of parasitic disease-producing germs or other functional disturbance. Parasitic life may therefore be called a struggle between two modes of vitality through two sets of organic cells, the one adventitious and hungry, and the other normal to the place and conservative, both so far degenerated as to be unable to elaborate for themselves a supply of food, and depending upon a supply to be furnished by a third agency of cells, which being a definite and limited supply, may prove insufficient for both. This is obviously true in the case of the tape worm, which absorbs an immense proportion of the nutritive matter required by the general tissues of the body. In many cases the parasite draws upon special parts and selects special nutriment to the damage of a special function of the host.

When the Rhizocephala (saculinas) infest the hermit crab (*Pagurus*), the female germ glands are never developed in the host. The growth of the host is not stopped but its breeding powers are. The larvæ of Trematoda, boring worms, infest the water snail, Lymnea stagnalis, and, in like manner, destroy its fertility without apparently affecting its general health in other respects. This is very curious when it is considered that the plundered nutriment goes almost exclusively to the support and development of the eggs and young of the parasite, which thus perpetuates his own worthless stock by the very means that should give a prog-

eny to his host. It is not less remarkable that the larva of a certain fly, the "*Cuterebra emasculator*, in very numerous instances, destroys the testes of various American species of squirrel without affecting the other vital functions." (Semper.)

The cause of the degradation and loss of functions in parasites and co-operatives is and can be due to nothing else than disuse. If one organ can become reduced to a rudimentary state by disuse, so may any other or even all providing some means survives for the performance of their functions, or so much of the functions as are necessary to the growth of the animal to maturity, and the formation of the eggs and embryos for the next generation. It is related by Caleb Wright that in India there have been many religious devotees who have rendered one arm, and in some cases both arms, perfectly rigid and functionless by holding them aloft in one position for a number of years. At first it is necessary to lash the arms in the upright position, as it is not possible to keep them so voluntarily, but in a short time the muscles and sinews become rigid and beyond voluntary control. Of course, a person so situated is unable to help himself to food or otherwise, and must be served by others as gullible though less devoted than himself. If we should imagine the process of self-disuse carried somewhat further, and the subject, instead of taking his food in the usual way, to receive a perpetual transfusion of blood from another person of sufficient health and strength, then the digestive apparatus of the recipient might lie dormant all his life, and his stomach, with its appendages, and the respiratory machinery, might become rudimentary. Extravagant as this seems it is just what takes place in the case of the Rhizocephala and some other crustacean parasites. However sweeping the degradation and elimination or substitution of functions, the reproductive organs are always excepted. These obviously can never be superseded by proxy or substitution, and never are or can be aborted without the extinction of the race. All the activities of life refer to the preservation of this thread of vitality from generation to generation. And the machinery for the preservation of this thread is the only thing which is absolutely essential in anatomical structure, and in cases of degradation, nature will sometimes let *everything* go *but* that—senses, brains, muscles, stomach and intestines. An animal race in the condition of these parasites has returned to first principles. The long process or selection by which with differentiation and heredity it acquired and maintained a complicated anatomy and functions has all been undone, unraveled, as it were. Every accessory and subordinate function has been lost; only the two great principles of animal existence, viz., accretion and reproduction, remain in their simplest form—the two principles which include all the necessary functions of existence from which and within

which they were all differentiated, to which they are all subordinated, and back into which they have now subsided.

The history of parasitic and sedentary animals includes a youthful or larval stage invariably more or less active, in which the animal possesses some animal functions, at least locomotion and the necessary organs for it, and a mature stage in which it only vegetates in the interest of reproduction, and in which a part and sometimes all the animal functions are lost. The larval history of a parasite must indicate the race history of the tribe to which he belongs, with greater or less fidelity, and so we are bound to suppose that the ancestors of every parasite and sedentary tribe were active and self-supporting and not at first parasites. We have a few examples of partial and unfinished parasitism which confirm this view.

Semper mentions that some crustacean parasites, whose present mode of life requires no organ of locomotion, still possess their swimming legs.

There are a great many parasites infesting various animals, especially marine animals, both inside and outside; and it often happens that the *endo* parasites are of the same species as their friends on the outside, the *ecto* parasites, but in almost every case there is a greater or less degradation of structure in the one on the inside as compared with the other. Among the many parasites infesting the Holothuriæ (sea-slugs) is the *Eulima*, a mollusk that lives on the skin of the sea-slug. It also is found on the star fishes. It is in all particulars a univalve mollusk except that it has lost its organ for gnawing and masticating its food, an organ that is common to all univalves but now useless to the Eulima, which lives on the slimy secretion of the host which it takes up by suction.

Another Eulima inhabits the inside of the Holothurian, differing but little from the outside one and destitute only of the masticating jaw or rachis. There is another species of Eulima parasitic on the Holothurian, fixed immovably on the outside, and having his jaw developed into a trunk or proboscis which is inserted through the hide of the host and sucks up all the nourishment required. The proboscis performs the function of anchoring the parasite, an office usually performed by the foot. But the foot is thus rendered useless and is now aborted. Locomotion not being indulged in, eyes are not necessary, and they, too, are aborted. On the other hand, the much-imposed-upon sea-slug entertains a number of endoparasites free, which roam about his intestines and appropriate whatever they fancy. Some of these are Trematode worms, others small Crustaceans belonging to the Copepods, Cyclops, &c. They are probably comparatively new at this sort of life or are subject to frequent disturbance because they are not mutilated as yet

but still retain their organs, locomotive, digestive, &c. Among the most curious cases of parasitism is that of one sex on the other in the same species. The differentiation by which hermaphrodite or bisexual animals were succeeded by the unisexual, must have been a gradual process, as all natural processes are, and, doubtless, required a great number of generations, and the first results of it must have been animals that differed from each other in no respect whatever, excepting a better development of male glands and a corresponding suppression of female glands in one, and a better development of female and a corresponding suppression of male glands in some other. As mentioned before, the Amphioxus, the lowest vertebrate, is in this condition of sexual equality. This sexual differentiation is by no means a unique phenomenon. It has taken place independently in very many lines of animal development, in various families of Insects, Worms and Mollusks, and also in plants. But subsequent to this primitive equality circumstances have, in a great many cases, sprung up to create and widen distinction between the sexes. The offices assumed by the sexes are usually complementary of each other, so that each in laying down a function has taken up another, and what is laid down by one is taken up by the other. For example, whilst among monogamous mammals it might be possible for the male to suckle the young equally with the female, among the polygamous ones it is manifestly impracticable as a rule, and so the male mammæ are generally rudimentary. But as a rule the polygamous males, in consigning the young to the care of the females, have taken upon themselves the common defense of the family, and anatomical structure following this division of functions, the female has become possessed of the well developed mammæ and the broad pelvis, while the male has the heavy shoulders, narrow pelvis and rudimentary mammæ. In this, as in all cases of differentiation, the assumption of a new function or the intensifying of an old one, is necessarily accompanied by and, in some sense, dependent on a corresponding abandonment and consequent suppression of another function. Parasitism being always followed by a deterioration of function, the result is not altered by a mutuality of parasitism. Everyone loses the power to do for himself that which he habitually puts upon another to do for him, regardless of what he may do in return for that other. In one thing the sexes were at the beginning, and in the very nature of things are always bound to remain, mutualists and equals, that is, in the essential organs and functions of reproduction. But in everything supplementary to this, one sex or the other may assume or shirk out of all duties and correspondingly increase or diminish its structure and function. The female tooth and nail may be sufficient for the family defense, or her industry sufficient to supply the family larder, in which case the

demand for masculine exertions may decrease, and a shrinkage of masculine force may follow. This happens in a great many cases.

Among the parasitic Lerneans described above there is often a great disparity in the sexes. Since both male and female are parasitic on some third party, the male need not do a thing to support the family, and so he has acquired the most remarkably shiftless habits and reduced anatomy. He generally retains his sense and locomotive organs, while the female loses hers, but the latter obtains a size from ten to one hundred times that of the male. And it often even happens that the male becomes attached as a parasite to his big partner, establishing himself upon her sexual organs. The same state of things occurs among the nematode *Sphærulariæ.* In some species the sexes do not greatly differ. In others the female is three times as large as the male, while in still others the male worms, vastly reduced in size but retaining their form, occupy the female matrix and remain parasites of their partners in that position; and, lastly, there are cases in which the males, parasitic in their females, are reduced in structure so far that little or nothing remains of them except the organs of reproduction. It might be thought that parasitism and its accompanying anatomical degradation could scarcely go further with safety to the main chance, which in every race is its reproduction and perpetuation, but here is a worse case.

The rat entertains a nematode parasite which sports the name *Trichosomum Crassicanda.* The female is 2.5 millimetres long and the male one-fifteenth as much. The male lives in the uterus of the female, and has no complete digestive apparatus of its own but has to be fed by the female. Sometimes five of these males are found in one female.* There are a good many crustaceans and insects of which the females alone are parasitical, while the males remain free and take care of themselves. The two sexes, therefore, differ greatly in form, the female being hatched as a parasite, and remaining during her whole life close to the spot in which she was born, while the male in the case of some of the insects assumes wings and has a gay and varied existence.

Not less remarkable than the foregoing is the history of the *Diplozoon.* This was at first thought to be a worm with two heads and two tails. But it was subsequently found to be two worms soldered together. They are said to be hermaphrodite from the time they are hatched from the egg till toward maturity. In their youthful days they are furnished with cilia for producing locomotion, and with a pair of eyes, and also a small ventral sucker and a dorsal teat or papilla. At maturity they settle in pairs on a host, preferring the gills of a fresh-water fish, each pair crossed like the letter X and fastened together by the teat and sucker, in which position they become soldered together and remain so for life.

* Van Beneden, 251, on the Authority of Leuchart.

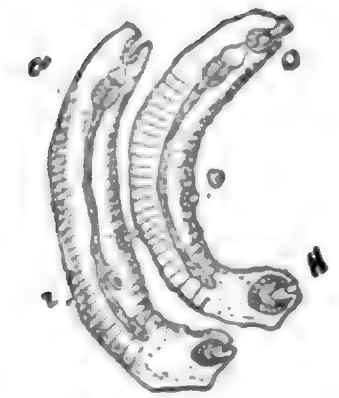


FIG. 95.

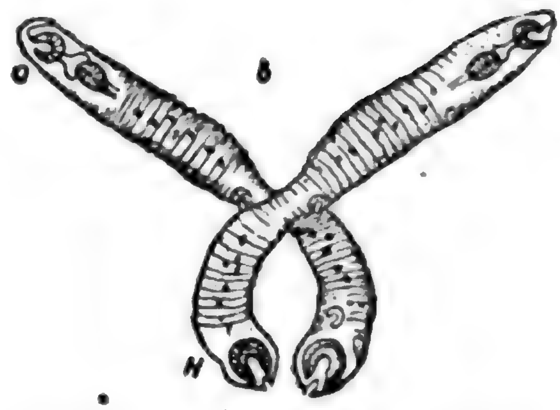


FIG. 96.

Fig. 95. Two young *Diporpa* (or *two buckles*) beginning to attach themselves together.
O—Mouth. Z—Papilla. G—Sucker.
Fig. 96. Process complete, the animal being now called Diplozoon (*double animal*). (*After E. Zeller.*)

They each lay eggs which are deposited on the gill of the fish and hatched there.

These worms are hermaphrodites, but, as is common amongst this class, they are probably not self-fertilizing but require to be paired, each being *female* to the *other.* This peculiar sort of marriage takes place with the *Lymneæ stagnalis*, or pond snail. Each individual is both male and female, but the position of the organs is such as to render self-fertilization impossible, so each one becomes a male to a second party and a female to a third at the same time; from which peculiarity they are sometimes observed joined together in a long string. The separation of the sexes is among the early differentiations by which a loss by one half of a race of one half of its sexual functions and by the other half of the race of the other half of such functions, brings compensation in the establishment of co-operation between individuals, followed by family and social relations.

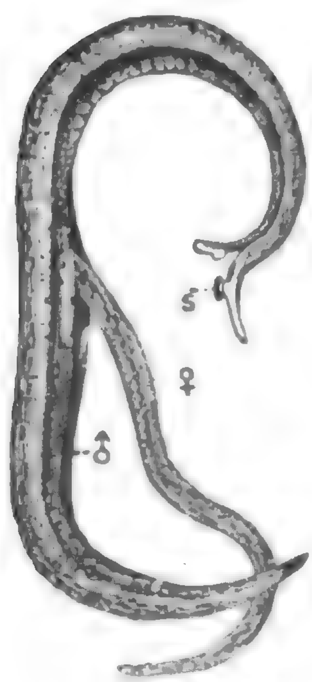


FIG. 97.

Fig. 97. A Trematode worm, *Distomum hæmatobium*; a parasite in the veins of man. Male and female together, the latter contained in the *gynecophorus*, or wife-holder.

♂—Male.

♀—Female.

s—Sucker.

Fig. 97 is a trematode which makes its home in human veins the male the larger in this case, and provided with a sort of pouch for holding his partner.

There is a parasitic nematode worm called *Syngamus trachealis*, which is developed in the tracheal artery of fowls. These worms are sexual and they are soldered together in pairs—a male and a female.

Van Beneden has a chapter on "parasites that are free when old." These he calls parasitic in youth instead of old age. The examples he gives are such as the Ichneumon fly and other hymenop-

terous insects—of which there are thousands of species—that deposit their eggs in a caterpillar or other larva, or, as in the case of the sphex, after depositing their eggs in a hole or nest, paralyze another insect or worm and place it in the cell with the egg to be food for the young one as soon as hatched. The young deposited in the bodies of others, as soon as hatched, feed on the abdominal juices of the tissues by which they are surrounded, and often entirely consume their host.

While this is another phase of parasitism I do not regard it as contradictory to the principle announced above, that parasitism comes from the disuse of functions once possessed, and therefore culminates in old age. The disuse of organs in a parasite and their consequent suppression or abortion is precisely the same process as that by which the rudimentary organs are formed in all the animals. Wherever we find a rudiment in a vertebrate (or an invertebrate) that rudiment is either functional or comes nearer being so in the embryo or youthful stage than in the adult. In *all* cases the suppression of the organ proceeds as the animal grows older.

The infants of all animals are helpless in the first moments of existence, and must receive food or other attention from some quarter. In the case of mammals the parents take care of their young, and develop a natural supply of food for them. In the case of the lowest marine invertebrates the water, into which they are born, carries food directly to them. If a human mother should feed her baby on cow's milk instead of her own, the mother would become, in one sense, a parasite on the cow, and it would correspond with a loss of lacteal function on the mother's part. The child is not parasitic any more by getting its milk from the cow than if it subsisted in the usual way. It is simply an undeveloped dependent in either case. The young of the Ichneumon and Sphex are likewise helpless infants, in whose reach food is placed by the precaution of the parents. The adults, in levying on their fellow creatures for the sustenance of their young ones, are like their human brothers, who go to the butcher shop, the dairy, the bee-hive and the hen-house for food to support *their* young (and themselves, as well). The whole of both proceedings only exemplifies the general fact spoken of above, that in animal life such co-operation of tribes as enables a tribe to supersede and get rid of some of its functions by having them performed by others, is an essential means of progress. It tears down some old structure which can be got along without, thereby making room for something else. It does not furnish the new function which is now within the possible capacity of the tribe; the other stimuli of the surrounding environment must do that—if it be done at all. In the case of the favored races, as Man and the Ichneumon, the environment finds stimuli to build new functions or intensify the old that are left,

and so the animal is more or less active, and keeps his wits about him to the end of his days. But the Sacculina andthe Tæ nia are like mechanics whose work is done by machinery better than they could do it themselves. They are deprived of their function, and if another is not developed they are forced to become parasites or tramps.

CHAPTER XXVI.

FUNGI.

In order to understand more fully the relationships between the animal and vegetable kingdoms and the intimate nature of the dependence of the former on the latter, a study of parasitic vegetation, especially of fungi and ferments, is essential. Vegetable parasites, like the animal parasites, exist in every degree of dependence on their host, and with every degree of reduced or lost functions and anatomical structure.

The parts of a complete plant are such as should enable it to take its nourishment direct from the mineral kingdom and elaborate it into food, or have it done in its own organism. These parts, in terrestrial plants, consist of roots to take up moisture, with carbonic acid, ammonia and various minerals; of stems with variously formed cells and ducts for the passage and storage of juices and nutriment; of leaves furnished with pores for the exhalation and inhalation of moisture, and with chlorophyl cells for the decomposition of carbon dioxide. The root also by its penetration into the soil makes a firm support to the structure, and gives it a local habitation. The essential normal activities of such plants are chiefly to take from the carbonic acid of the air its carbon, which is elaborated into starch in the chlorophyllian cells of the leaves, and sent thence into the roots and stem to be further modified, digested and assimilated, and to draw moisture and nitrogenized matters through the roots. There are many plants not possessed of either roots or leaves but which nevertheless accomplish substantially the same purpose with simple substitutes for those organs. But there are likewise many plants in which some of these essential parts are wanting, and which nevertheless have no substitute for them. These are the true parasites, and they depend upon other plants to perform for them the functions that they are unable to perform for themselves. Like the animal parasites they never lose their reproductive functions. On the contrary, their parasitism taking off the burdens of the elaboration and digestion of food, and the formation of the organs necessary for those functions, nearly the whole of the stolen resources of the parasites may be devoted to their reproduction. Consequently we find that the reproductive spores of fungi are inconceivably numerous.

Fungi are frequently colored, but in no case do they possess the green chlorophyl cells. Their organs, which chiefly relate to the reproductive function, are often curious and elaborate. They have neither leaves nor roots. Instead of roots they have fibrous organs like suckers, which penetrate into the tissues of the host to receive and convey the nutrient fluids. These fibres are collectively called the Mycelium. Where the Mycelium penetrates the soil it still does not take up mineral matters as a plant does, but only juices of decaying vegetable or other organic products.

The fungi, or Mushrooms, belong to that series of the Vegetable Kingdom called the Cryptogamic. This series includes, besides the Mushrooms, the Mosses, Lichens, Liverworts, Sea-weeds, or Algæ, and Ferns or Brakes. The Mushrooms are divided into six families, and these are subdivided into orders to the number of thirty-two in all,* and these again into a great number of genera and species, all bearing names of a size out of all proportion to themselves, but generally significant of some function or structure.

In the first family (the Hymenomycetes) are found the Agarics, which are known to everybody as the umbrella-shaped mushrooms and toad-stools. The slender fibres of their Mycelium traverses the fat soil, and there is a thick stem surmounted by the cap or *pileus.* On the underside of the pileus are suspended the gills, or *lamellæ,* like little curtains hung by one edge and distributed like rays or spokes running from the center to the edge. There is a delicate membrane spread over the under surface of the pileus following the indentations made by the gills, and covering their sides so that it appears in shape like a folded fan. This is the hymeneum or spore-bearing membrane, and the spores drop out of it when ripe. The difference between a spore and a seed proper, is this: A spore is a simple cell formed by the union of a male and female germ containing (probably undifferentiated protoplasm, but) no starch or sugar. A seed is a more advanced and differentiated structure, because beginning as a cell formed by the union of the male and female elements, its development and differentiation has begun, and by the time the seed is ripe the embryo of the new plant is formed within it, and about the embryo is deposited a quantity of starchy or other nutritive matter, which is to be consumed by the young plant after it begins to germinate. The spore cannot have this deposit because its parents have no machinery for its elaboration—they eat, but parasite-like save nothing—besides the spore don't need it, for its destiny is to feed where the table is already spread with organic food—a seed feeds on minerals *after it is weaned.* A spore never does.

*This is according to M. Cooke, from whose work on fungi many of the facts in this chapter are derived.

Some of the orders of the Hymenomycetes, instead of having gills or curtains on the underside of the pileus, have tubes or pores, others have warts or spines, others are nearly smooth, the hymeneum in each case covering all and developing the spores.

Another order, *Clavariei*, is club-shaped, or cylindrical, and the hymeneum covers the outside all round. In the sixth order of this family, *Tremellini*, the fungus is folded and lobed like the convolutions of a brain, and is of a gelatinous appearance. Throughout the gelatinous mass there are filaments or threads, the ends of which, coming to the surface, bear the spores, which are dropped on the surface of the Tremella like fine white dust. The color of this fungus is a fine, golden yellow. The spores are from .006 to .008 of a millimetre in diameter, about $\frac{1}{4000}$ part of an inch.

The second family is named the *Gasteromycetes*, and are mushrooms with an internal cavity or belly in which the spores are generated. Some of them are subterranean. The puff-ball, Lycoperdon, belongs to an order of this family. Everybody has seen them when ripe, kicked and blown about, distributing their spores like dust everywhere. One of these balls has been known to attain the diameter of a foot. Some of this family, when ripe, attract water from the air and *deliquesce* (like some mineral crystals) and liquify. Others, as the *Nidulariacei*, when ripe burst open at the top, showing the spores on infinitesimal stems or spicules, like little eggs in a nest, as the name implies. There are several subterranean genera connected with this family.

The third famliy is *Coniomycetes*, or *dust mushrooms*, so called because they develop mostly into spores and, in many cases, are without any mycelium (roots) or stems. Some of them get into crevices of the bark of dead trees, form their spores under a little cap or perithecium, and when mature drive them out at an orifice at its apex. Others, as the *Melanconiei*, "black dust," have a network of mycelium, very fine and close, covered with a sort of cuticle. The spores are formed between the two and expelled through the latter.

The *Torulacei* constitute an order in this family. They consist of nothing but chains of spores linked together; sometimes the spores are simple, in other cases are divided by cross partitions, which finally separate the parts into so many spores, and sometimes a simple thread or elongated cell is subdivided by the septa or partitions into spores. There are three other orders in this family, all of whose genera are parasitic on live plants. A sub-order entitled the *Ustilagines* includes the smuts and bunts of grain plants, and another sub-order, the *Uredines*, includes the red rusts of wheat and grasses.

The fourth family is the *Hypho-mycetes* (*woven* or *webbed* mushrooms). These include the moulds, some of which are of microscopic dimensions

but of great beauty and elegance. In some the spores are formed on threads which are united so as to form a compound stem. The *Dematiei* (black moulds) and the *Mucedines* (white moulds) belong to this family. The threads or stems of the *Dematiei* have an investing or cortical layer like bark, which may be peeled off, and both the threads and spores are generally more or less colored a dull, dark color, as if charred or scorched. In many cases the spores are large and elongated, and sub-divided by several cross-partitions or septa, the protoplasm of each apartment containing a nucleus. The *Helminthosporium* constitutes a numerous genus of the black moulds, and is found in patches like velvet on decaying herbs and old wood. The spores are produced on upright stems or threads shooting up from the matted mycelium, and grow out of the top or sides. The cortex or bark of the stem adds to their stiffness. Under the microscope these stems appear jointed like canes in a cane-brake.

The most important genus of the *Mucedines* is the *Peronospora*. The various species of this genus are parasites on living vegetables, and one of them is the cause of the potatato disease, which has played such havoc with the Irish potato. In this genus there is a delicate mycelium which penetrates the intercellular passages of living plants, giving rise to erect branch threads which bear, at the tips of their outermost twigs, oval or spherical-shaped spores called *conidia*. There is no cortex on them. Deeply seated on the mycelium within the substance of the foster plant other reproductive bodies called *oogonia* originate. These are spherical, more or less warted and brownish, the contents of which become differentiated into vivacious zoospores capable, when expelled, of moving in water by the aid of vibratile cilia. A similar structure is found in *Cystopus candidus*, a genus of the Uredines. We shall find some of the algæ with active spores also.

The fifth family is that of the *Physomycetes*. In these the spores are produced inside of little sacs called sporangia. These sporangia are borne upon threads, and each contains a number of the spores. When ripe the sporangium bursts and scatters the spores. One genus grows in the form of a blackened felt incrusting old wine bottles in cellars. But the most interesting of this family are the Mucors (*Mucorini*). These resemble the mucedines but differ in the method of producing the spores. In some species the sporangium appears to be the result of a "conjugation," or sexual union between two of the upright threads. The Mucors are not parasitic on live vegetation, but only on that which is dead or decaying. The *Mucor Mucedo* grows spontaneously in fresh horse-manure if the latter be confined in a damp atmosphere under a bell-glass for a few days, and will cover it all over with an "immense white mildew." Growing out of the mycelium, which is spread out, are

numerous white filaments, each of which bears a sporangium on top. The spores can be sown and produce mycelium in a solution of sugar or other nourishing fluid if excluded from the air.

The sixth family is called the *Ascomycetes.* In these the sporangia are themselves contained for a longer or shorter time in larger sacs called *asci.* In some the asci soon disappear, leaving the sporangia free; in others they persist till the spores are mature, when they burst and liberate them. Some are found chiefly on animal substances. Others occur on living plants. The order called *Perisporiacei* contains many destructive genera, as the Hop Mildew, Pea Mildew, Rose Mildew, &c. They cover the surface of leaves &c., with a thick, white coating.

In some of these organisms several different kinds of fruit are produced from the same mycelium, sometimes as many as five or six. They call to mind the alternate generation of some low animal forms. There is an order of underground bulbous fungi belonging to this family. They are called the *Tuberacei*, the most important genus being the edible delicacy called the truffle.

Many of the fungi are self luminous, probably from phosphorus contained in their tissues. One example cited by Cooke was reported by a traveler in Australia. A large specimen of an Agaric, sixteen inches in diameter, was found and hung up in a sitting room, where it gave light for four or five nights—till it dried up. All parts of the Agaric, except the top of the cap, give this light—of a pale greenish tint. Certain species, the Boletus luridus and others, on being cut or bruised exhibit an intense and, in some cases, a vivid blue. This color is taken on very quickly, almost instantaneously. This is attributed to a rapid change in the molecular constitution of the plant on exposure of the tissues to the air. Many of the fungi contain a milky juice, and when the flesh is cut or bruised and this juice exposed to the air its color turns to a dull livid green.

Fungi are generally strongly odorous, and disagreeably so. Most of the fleshy forms smell of nitrogen while decaying. "*Peziza Venosa*" when fresh has a strong odor like aqua fortis (nitric acid). The growth and decay of fungi are both extremely rapid. A puff-ball or a toad-stool will grow enormously in a night, and in the same length of time a mass of paste may be covered with mould. "In a few hours a gelatinous mass of *reticularia* will pass into a bladder of dust, or a *coprinus* will be dripping into decay." These facts point clearly to the delicacy of the molecular constitution of these fungi, and the extreme fickleness of their constituents. Nitrogen, which appears to be largely concerned, forms always exceedingly unstable compounds.

The spores of fungi are disseminated through the air like dust, and

are entirely impalpable and invisible singly, the largest of them requiring to be magnified 360 diameters under the microscope before they become visible. Their number is inconceivably great, and whenever any spot furnishes the proper conditions of temperature, moisture and organic matter, whose chemical bonds are not too strong or have been loosened by decay, some of them are sure to find it speedily. Certain species are so abundant in the air that it is almost impossible to keep them out of even closed vessels, especially such as the common moulds *aspergillus* and *penicillium.*

Gardeners often raise agarics by simply making a bed of mixed horse and cow ordure, in which the spores are expected to find lodgment and germinate. It may be assumed, in some cases, that the spores have been eaten and have passed through the stomach unhurt—and not only so, but it is even supposed that the germinating powers of the spores are only brought out better by the process.

There is variety both in the mode of producing the spore or seed and in the manner of its development into the plant. On the supposition that the fungi are degenerate plants that have lost the chlorophyl organs, we might expect to find some trace of their ancient relationships in their mode of development. In some cases observers have been able to do this.

The development of the *Conio-Mycetes* is proved to be an alternate generation. That is, the spore does not grow at once into the full fungus conio-mycetes, but produces what is called a *pro-mycelium.* This is a long tube of thin membrane, and into it the protoplasm of the spore enters, doubtless dilated by the absorption of water. The tube takes a curved shape and is rounded club-like at the end. On the end and sides of this tube, or promycelium, four spicules, or small projections, are formed, and on the ends of these are developed a second set of spores called sporules, and these then germinate and proceed to develop the true mycelium for the full grown plants. The first set of spores, those that develop the promycelium of the coniomycetes, are called pseudospores to distinguish them from the last ones. This mode of development by alternate spores is quite common among these fungi. Now we will compare this with the development of the Bracken Fern. This is classed as a cryptogamic plant. When the Fern is mature it develops sporangia on the underside of the leaf stems. In these sporangia the spores are developed by a fissive *asexual* process. When the spores are set free they germinate and sprout into a small cellular plant which is called a *prothallus* (first twig). The protoplasm of this prothallus becomes differentiated into male and female. An antheridium containing active antherozooids (or male cells) being formed above and an embryo cell below. The antherozooids move down a canal by means

of cilia, and impregnate the embryo cell, which thereupon germinates, sending roots into the soil and growing above into a fern. The juices of the prothallus furnish nourishment to the Fern till its roots are able to sustain it independently. (Huxley's Biology.) Thus the Fern represents in its development two forms of reproduction, the first asexual by fission, or the repeated subdivision of a single cell, the second sexual, or the reunion of previously differentiated positive and negative, or female and male, cells. Moreover the prothallus is a cellular plant, while the stems of the Fern are vascular, and the fern is the lowest of the vascular plants. The development of the coniomycetes, as above described, appears curiously imitative, in a degenerate sort of way, of that of the Fern. Its pseudospore answers to the spore of the Fern, the promycelium represents the prothallus, the mycelium stands for the roots of the mature Fern, the little spicules may be the remains of antheridia, and the sporules the impregnated embryonic cells resulting from an internal cryptogamic union of sexual elements.

Since it is absolutely certain that the fungus is a degenerated organism in the sense of having lost functions, the foregoing coincidences point very suggestively to an ancestry having much in common with the ancestry of the Bracken Fern.

The Cystopus, one of the Uredines or rusts mentioned above as a sub-order of Coniomycetes, also has an interesting history. It has two kinds of reproductive organs, *Conidia*, which are formed in chains on the surface of the plant, bursting through the cuticle, and *Oögonia*, which are spherical bodies developed on the roots of the mycelium down among the tissues of the plant on which the *Cystopus* makes its home and its living. These last are called the "resting," or "winterspores," and are the ones that survive the winter and germinate in the spring, the others being killed.

When the conidia are placed in water they absorb moisture and swell and the protoplasm inside of them is developed into zoospores, five to eight of them in each conidium, from one end of which they are expelled one by one. At first they remain attached around the mouth of the conidium, but afterwards become free and develop two tails or vibratile cilia, by means of which they swim around in the water like the zoospores of algæ. The development of these zoospores is accomplished within three hours after the conidium is put into the water. In nature, the water from rains lodging on the leaves in damp and shaded localities causes their germination, and they go on producing mycelium till stopped by dessication or winter.

The development of the oogonia produces zoospores in just the same way but in greater number. After their expulsion they enjoy their freedom in locomotive activity for two or three hours, then their movements

abate; their cilia disappear, the spore becomes immovable and takes a globular form and becomes covered with a cellulose membrane. "Afterwards the spore emits from any point whatever of its surface a thin, straight or flexuous tube, which attains a length of from two to ten times the diameter of the spore. The protoplasm enters this tube and on growing plants the tube forces its way into a stoma, or pore, of the leaf of its victim, and spreads its branches, forming the mycelium in the intercellular passages. These oogonia are matured on dried leaves during winter, which kills the rest of the plant.

By some, the Peronospora—the potato fungus—is thought to be related to this Cystopus, although it is generally classed with the Mucedines. It has the two modes of reproduction, by summer, Conidia, and the winter Oogonia, the same as described above. There are some other genera in which this mode prevails. Among the Physomycetes and Ascomycetes, fifth and sixth families above, there are also two modes of reproduction; one by the sporangia, and the other by the conjugation of two stems and the resulting development of zygospores—literally "yoke-spores." The process, in the case of Mucor phycomyces, is thus described. Two slender threads lean up against each other and are in close contact for a considerable part of their length, the surface of contact becoming uneven by parts of each protruding into the other. Then the two ends arch back and over towards each other, the tips touching. These then enlarge and unite into a single globular spore, finally covered with warts or prominences when ripe.

Another of the Mucors, the *Rhizopus-nigricans*, produces a zygospore in a manner somewhat similar. First cylindrical processes are formed on two threads, which then grow toward each other and unite their ends, which become cemented into one mass which swells into an ovoid body. A stricture is formed on each side of the swelling which, growing deeper by the time the zygospore is mature, cuts it off and drops it.

The sexual impregnation that takes place in the species of the *Saprolegnici*, one of the orders of the *Physomycetes*, is also very remarkable. An oogonium is first formed on top of a short stem which grows from the mycelium, and it appears to be the receptacle of female cells, a sort of uterus, in fact. Now, below the oogonium and from the stem on which it is perched, a tube is developed, which, growing out of the stem, curves upward and back toward the oogonium, until its end touches it and penetrates its shell. Protoplasm then passes into the oogonium from the tube, accompanied with granulations and some very lively corpuscles, which are supposed, with probability, to be spermatozooids. The male tube is called an antheridium, it evidently answering the same end as the anther of flowering plants. It occurs in some form in a great many species besides those named here.

Like many of the parasitic worms, certain Fungi possess alternate forms of reproduction; form *a*, for example, producing spores that sprout into form *b*, quite different from *a*. But the spores produced by *b* will, upon germination, develop into *a*, &c. Sometimes there are three or four terms instead of two. The red rust of wheat and grasses reproduces the corn mildew.

Again, many species possess several forms of reproductive organs and several sorts of fruit, *apparently* from the same mycelium, and in some cases it is pretty well proved. In all these particulars low forms of animal life are found to imitate these fungi.

There are some fungi that do not propagate by means of spores. Their entire structure consists of similar cells, and they reproduce by fission, or the division of cells, and so never develop by the metagenesis or alternate generation (for such it is) of seeds or spores. Such a plant is the Torula.

A singular feature of the Fungi is their choice in the matter of the host they shall patronize, the same kinds of fungus having become differentiated to the same mode of life and the same food. Several different kinds live on wheat and the grasses. One, Puccinia, specially favors Indian corn, another attacks celery, and a third plum leaves. The *Peronospora infestans* is the potato fungus, while other varieties of the same affect spinach, onions, lucerne, &c. One, *Oidium*, attacks grapevines, while another attends to hop-vines. The Ascomyces deformans lives on peach leaves; a Bullatus on pear leaves; a Juglandis on walnut leaves; a Pruni on plum fruits. Some species live on the cotton plants of India, while one, Torula, confines itself to the unripe pods. In short, scarcely a plant can be named that does not have its favorite mould, rust or mildew. But the fungi do not confine their operations to plants, living or dead. They are found at times on bone, horn, leather, &c., and many varieties find a living on live animals of all sorts. A white mould is very destructive to the common house-fly. Another envelops with its growth, spiders, wasps, moths and butterflies, and many dead insects are found covered with mould under circumstances that indicate the mould as the cause of their death. Many diseases of man and other animals arise from these vegetable parasites. The water-brash plant, *Sarcina Ventriculi*, found in the fluid of that disease, is an example. Tetter and ringworm are due to a fungus, and so it is supposed is the disease of the hair called *Plica Polonica*. The so-called germ diseases belong to the same class (see Chap. 31).

On the other hand, the fungi furnish food to a good many little animals of various kinds. And again, a certain section of them, under the name of Ferments, render service to man that could not be dispensed with. It is a question how far the various sources of living affected by

the various fungi may react to modify them, but they are no more exempt from such influences than the higher organisms, and it may safely be assumed that the differences between them are, in many cases, due to their different food and habit of life.

There is much reason for believing that many of the fungi are simply degenerated algæ. The algæ are cellular; some of them consist of only a root-like body, some of only a branching naked stem, some of just an expanded leaf, while some of the most complex may have all these parts. Those algæ that have something like a root do not get any nourishment through it. It serves to hold on by, but is not a genuine root, and many have no root of any sort. The fucoid seaweeds are sometimes 30 or 40 feet long, and the algæ grade all the way down from that to a microscopical size. These minute algæ belong to several orders, as the Desmids, Diatoms and Palmellaceæ. They consist of a single spherical cell each. At maturity this cell is divided by a partition across the middle; each half becomes developed into a single-celled plant like the first, in the case of the Diatoms and Desmids generally, but it may be divided into four parts, as in the case of some of the Palmellaceæ.

Protococcus is the name of a genus of the last order. Its coloring matter is often red mixed with the green of its chlorophyl. It is found everywhere, from the snows of Greenland to the hot water of the Red Sea, and flourishes equally well in either. Growing with surprising rapidity, it scatters its cells so thickly through the snow or water as to give its color to either. The cells may become dry and will not lose their germinating power in several years. They are carried everywhere by the winds, and may be found in the mud of roof gutters and in rain water cisterns. According to Huxley, the cell wall is tough, transparent and structureless, composed chiefly of cellulose colored green, or red and green. Inside the, cell is viscid and granular protoplasm. Its size ranges from $\frac{1}{10000}$ to $\frac{1}{350}$ of an inch in diameter. It cannot grow in the dark, as does the fungus Torula. In daylight it decomposes carbonic acid gas, appropriating the carbon and setting the oxygen free. This power of getting carbon from carbonic dioxide is what chiefly distinguishes this and all plants containing chlorophyl from Torulæ and the other fungi. In the dark, Protococcus, like all other living things, undergoes oxidation and gives off carbonic anhydride ($C\ O_2$).

Sometimes the cell wall vanishes and the naked protoplasm swims about and may undergo division and multiplication in this state. There are many species of these small organisms that produce spores for propagation in addition to their other method of reproduction by fission. The spores are produced thus: Two individuals approach each other and develop a little tubercle at one end of each. These come into contact, the walls between them disappear, and they are cemented into one, form-

ing a tube connecting the two cavities. The fluids from the two cells meet and mix in the tube and form the spores. The old cells then drop off, leaving the spore tube or sporangium, as it is called, to mature and discharge the spores. This recalls the performance of the Ascomycetes in the production of the zygospores. Some species of Desmids and Diatoms produce spores without the conjugation of two individuals. They may be called hermaphrodites. The protoplasm of a single individual becomes granulated and turns to spores, which, from their active and restless movements in the cell and after they burst it open and escape, are called zoospores. In some cases cilia are developed from their shells, which have a forward and backward movement like microscopic oars, by which they move in various directions and spin around. They pause from apparent exhaustion, rest, and begin again.

They recall the zoospores of numerous fungi mentioned above. Where there is reproduction by both fission and spores, the latter, may be regarded as specially differentiated organs in which the necessary morphology and arrangement of molecules for going on is completed, but the function of which is arrested, to be renewed at a future time, while the former—fission—is to be regarded as simply the continuous growth of the same individual. Any organism grows by the continued segmentation or fission of the cells composing it, provided the cells remain attached to each other after the division. A man's hand is larger than a child's because the cells, after their repeated fission, remain together under the same roof of skin. In the case of the Desmid or Protococcus, the two or four pieces of cell after fission grow to maturity of size and shape, but instead of remaining together to form a compound organism, fly apart to remain simple. The cells that result from fission in those organisms that *have* the spores *also*, may therefore not be able to renew the growth of the organism after it has once been stopped. They are to be compared with the cells in the leaf of a deciduous tree, that keep on subdividing and multiplying all summer, but die in the fall, and they recall the summer growth and production of summer mycelium and summer spores in the conidia, of the Cystopus, and other Uredines as related above. And the zoospores of the Desmid are to be compared with the "resting," or "winter spores," of cystopus—the products of the oogonia—and equivalent to the seeds of the higher organisms. In those species of the Protococcus, Diatom and Desmid among the algæ, and the Torulæ among the fungi, that never have any spores, no differentiation of reproductive functions and organs has taken place. The one cell contains the possibility of continuous growth by repeated division as long as the conditions of such growth endure, and on the termination of such conditions, the vital energy barred and deflected from going forward in ordinary growth is brought

to a halt in winding up the organism, as it were, leaving it in a state of tension or erethism, ready to unwind and start off again upon the renewal of the proper conditions, or, in other words, this undifferentiated cell must by turns grow and rest, unwind and wind up, become the leaf cell and the seed.

When an organism, as a Desmid, for example, comes to have spores, we may conclude that a differentiation has taken place by which the growing by the continuous division and multiplication is exclusively confined to one set of cells, while the function of reproduction or of the renewal of growing after it has been stopped is transferred exclusively to another set. There is probably an intermediate stage in which there are cells exercising either function, as compelled by circumstances.

We thus find a strong parallelism between the Fungi and the lower algæ in morphology and modes of reproduction. The resemblance is sometimes so strong between them that naturalists do not agree on which side of the line to place some of them. One order of the Physomycetes; viz., the *saprolegniei*, is claimed to be algæ, by some authors. Where the difference is pronounced, it consists almost, if not entirely, on the fact of the presence of chlorophyl in the Alga, and its absence in the Fungus. And there are the intermediate organisms in which, while chlorophyl in limited amount is present, it is yet doubtful whether it is the sole dependence of the organism for obtaining food. It is easy to see how such a plant having a case through which, by endosmose, it is capable of taking up fluid saturated with already elaborated vegetable matter, and also chlorophyl organs, of limited capacity, for seizing carbon from the atmosphere, might be placed under conditions in which it would get a better supply of food already elaborated than it could elaborate for itself. The very fact that any food could be got without the use of the chlorophyl function, would, to a greater or less extent, supersede and discourage its use, and such discontinuance of the use of the function must result, as in all such cases, in its final extinction, followed by the loss of the organ. The Fungus has unquestionably passed through this experience, and in thus quitting hard work and taking up easy work it illustrates the materialistic economy which governs the processes of differentiation. That is, whenever there is more than one way of accomplishing a vital end, the differentiations favor the cheapest way.

It must occur to everyone that essentially there is much in common between the Fungus and animal life. Especially is the animal parasite essentially like the Fungus parasite-on-an-animal, even to the food he consumes and the functions he performs. But in its dependence on getting food ready prepared into proteids and amyloids, in its inability to make starch, or decompose carbonic acid gas, and in its requirement of free oxygen, the Fungus is like all animals. We are very close here

to the boundary line between the vegetable and animal kingdom—if, indeed, we are not on the animal side of it. The difference between a Monera, or an Amœba, and one of the lower fungi, is not such as distinguish an animal from a vegetable, but, rather, one animal from another. The Amœba is locomotive, which the Fungus is not, except as a zoospore. The Amœba takes into his system with his food mineral matter, which he cannot assimilate and which he subsequently excretes. The Fungi also take in unnecessary and unassimilable mineral matters with the juices they absorb, and they remain in their tissues. Both excrete carbonic acid in respiration. The Amœba takes some of his food solid and some by endosmose through his ectosark. The Fungus gets all by endosmose in the simpler species, and by suction and absorption (which is much the same thing) in the differentiated species.

It has been stated that at times some of the Protococci float about in the water without their usual cellulose cover, and as formless protoplasm are still able to proceed with their functions of growth and division. This is a chlorophyl plant, and is supposed to live on carbon extracted from carbonic acid. But in this shape evidently it may come into contact with food particles and receive nourishment, as the Monera does, and thus be saved some work. And a frequent repetition of such experience would tend to establish a habit of going naked and absorbing the more liberal supply of ready-made food. It is extremely probable that this is precisely what happens in such cases as that of the naked Protococcus, as we know it does in the Monera which does not possess chlorophyl. But the fact that simple organisms live so close to the boundary line between the animal and vegetable kingdoms as to be able to wander back and forth across it, does not depend altogether on the foregoing inference, although it lacks but little of being a demonstration. Botanists can tell by spectrum analysis, and otherwise, whether coloring is due to pigment simply or to chlorophyl, and it is generally conceded that the *green* coloring of all plants is due to chlorophyl. But, as mentioned in Chap. 24, there are also *green* animals in abundance, and it has been asserted that this green is due to chlorophyl, in the case of the Euglena, Stentor, many Radiolarians and fresh water sponges among the Protozoa, in the polyp hydra of the Cœlenterata, and in the Turbellarian worms. In the latter the decomposition of carbonic acid gas has been proved to take place. This is precisely what we should expect. These little animals, originating from a vegetable ancestry and not sufficiently differentiated to be always in reach of prepared food, have so often had nothing to eat that their chlorophyllian apparatus has been brought into requisition often enough to prevent its decay.

From the foregoing it becomes perfectly plain how an organism, by a

change of habit, and a loss of an important organ and an important function, could pass from a vegetable to an animal mode of life; in short, how the animal kingdom has been derived and developed from the vegetable kingdom.

The Myxomycetes, or slime moulds, are masses of naked vegetable protoplasm. They may be obtained on the surfaces of decayed logs, leaves and other vegetable matter, or on grass, &c., near decaying vegetation. They are subject to movements called streaming, in which currents are observed to run in one direction awhile, then to reverse and run back. Sometimes this movement, by being more forcible in one direction than the other, results in slowly conveying the whole mass bodily.

These *slime moulds*, according to Prof. Bessey, are the counterparts of the Monera. He says it is not improbable "that in the Myxomycetes we have the *terrestrial phase*, and in the Monera the *aquatic phase* of a common group of organisms. The two are alike in structure and probably also in their affinities, and all the difference between them may, with probability, be referred to the difference of habit, the terrestrial of the Monera and the aquatic of the Myxomycetes. (Bessey's Botany, p. 207.) The slime mould being destitute of chlorophyl, although it is only vegetable protoplasm, cannot be distinguished from the animal Moneron, and the animal and vegetable kingdoms here occupy the same ground. The Protomyxa is an organism formed from this protoplasm, which, passing through several stages of development, returns again to protoplasm. (See Chap. 33.)

CHAPTER XXVII.

ORGANIC FERMENTS.

Beer yeast or alcoholic ferment is a minute, single cell organism which will live and grow in a variety of solutions. It is called *Saccharomyces Cerevisiæ*, literally, *sugar mushroom of beer.*

Brewers use two varieties of yeast in brewing beer. One is the surface variety and the other the sedimentary.

In the process of "working," the former comes to the top and the latter settles to the bottom. The temperature required is from 53° to 65° Fahrenheit, the surface variety requiring the highest temperature. The surface variety is also the more active; fermentation, when it is used, requiring but two or three days, while with the sedimentary kind it takes from eight to ten days. The increase of the yeast during the process is seven or eight fold. After the sedimentary fermentation the yeast found at the bottom of the vat is composed almost entirely of cells of a

single species of alcoholic ferment, Saccharomyces Cerevisiæ, and along with it microscopical quantities of lupulin, crystals of calcium oxalate, spores and mold. This deposit is of the consistence of a paste of yellowish white or yellow ochre color. The cells are round or oval, from $\frac{8}{1000}$ to $\frac{9}{1000}$ of a millimetre ($\frac{31}{100000}$ to $\frac{35}{100000}$ of an inch) in their greatest diameter. They are formed of a thin and elastic membrane of colorless cellulose and of a protoplasm, also colorless, sometimes homogeneous, sometimes composed of small granulations.

FIG. 98. *a—Saccharomyces Cerevisiæ.* Yeast of sedimentary beer. *b*—Same budding. × 400

There are in the cells one or two vacuoles containing cellular juice. The cells are separate, or united two by two. They multiply by budding. A swelling appears usually on the side but sometimes on the end of a parent cell. The swelling increases by the withdrawal of protoplasm from the parent cell, the vacated space in the parent appearing as one or more vacuoles.

If the conditions are favorable the same cell is able to produce several generations of cells, but by degrees it loses all its protoplasm, which at last unites in granules swimming in the midst of superabundant cellular juice. The cell then ceases to reproduce and even to live, the membrane is ruptured and the granular contents are diffused in the liquid. When the saccharomyces cerevisiæ is not in contact with a fermentable liquid it may remain for some time without becoming modified. Increase of temperature may increase the size of the cells from one-third

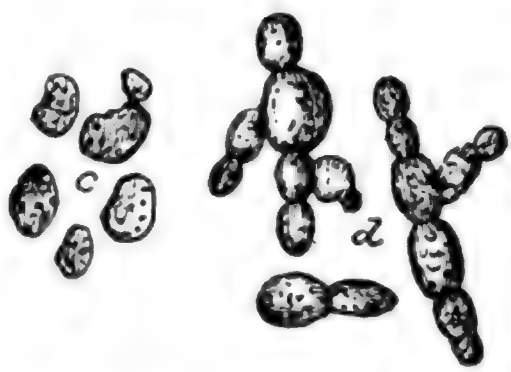


FIG. 99. *c—Surface yeast of beer* at rest. *d*—Same budding.

to one-half. The surface variety buds much more quickly than the sedimentary kind. In this variety also, the cells remain to some extent

united; as many as a dozen remaining connected in one bunch. The principal difference between the two kinds is in the time taken for budding.

The surface or high fermentation is the cheapest and quickest, but in sedimentary, or low fermentation, the temperature is so much lower that the *adventitious germs* that set up the vicious fermentations that constitute the *diseases* of beer are rendered inactive, and as long as the beer is kept cool it will retain its quality. Hops in beer are also used to defend it against the parasitism of Bacteria, which are killed by them.

As long as yeast is in contact with a fermentable liquid it grows only by budding, the new buds carrying the line of vitality, while the old ones are being gradually disintegrated. But if this budding process is arrested without destroying vitality, under certain conditions the organism goes to seed—that is, forms spores, so called. This operation can be brought about artificially by suddenly depriving the plant of nourishment, especially saccharine, and exposing it in a damp atmosphere or on a moist substance. Rees obtained spores in 15 or 16 days by washing the yeast in clean water several times during successive days, then decanting the water and drawing off all that was liberated from the mass, day after day.

Engel fixed up a contrivance, consisting of a mass of plaster of Paris, which he placed in a dish of corresponding shape. The top of the plaster he covered with yeast, fresh and free as possible from all fermentable fluid. In the dish around the plaster he poured water till it came within a centimetre (.39 in.) of covering the plaster. Over all he placed a glass cover to keep off the spores of the air. (The plaster was to suck up and supply steady moisture.) The vital energy of the yeast, now unable to construct any more buds, expends itself in forming spores. The oldest cells and those most impoverished in protoplasm "perish and break up." The more vigorous increase in size, their lacunæ (vacuoles) "disappear and the protoplasm is diffused uniformly in the cellular juice."[1] In from 6 to 10 hours from two to four "small islets" appear surrounded by fine granulations. These islets are bright and dense and gradually assume a spherical form. Twelve to 24 hours later each of these spherules is "invested with a membrane, very thin at first but which thickens by degrees and then shows a double outline when magnified 600 diameters." "The spore is then ripe. The mother cell thus contains from two to four spores." During their evolution the spores touch each other, forming plane surfaces at the point of contact. If there are only two spores each has a flat side; if there are three, each has two flat sides at an angle of 120° to each other; if there are four each has three flat sides if they are piled up; or only two at right angles to each other, if the four cells lie in the same plane. "When the spores ripen the thecæ (cases or sheaths) are moulded on them and thus assume their various forms. The theca of the dyads is elliptical, that of the triads is triangular with rounded angles, that of the tetrads in the shape of a cross," (i. e., in one plane) "is in the form of a diamond with rounded angles: in the tetrads, piled upon each other, the theca is tetrahedral. "When in complete maturity the membrane of the sporecase, or mother cell, which has become a fruit, is torn and allows the spores to escape. The thecæ themselves vary from .01 to .015 of a millimetre (.00039 to .00047 of an inch), and the spores from .004 to .005 of a millimetre (.00015 to .00019 of an inch") This going to seed, or production of spores, cannot take place in the absence of atmospheric or free oxygen. All the other functions of yeast, including its growth by budding, are carried on at the expense of the oxygen contained in the sugar of the infusion in which it works.

The foregoing is an account of Saccharomyces Cerevisiæ, but some other ferments will affect the alcoholic fermentation of glucose. *Saccharomyces Minor* is the name given to the ferment obtained from leaven of flour (Engel).

The fermentation of a saccharine medium by this is slower than by beer yeast. Spores enclosed in thecæ are produced in this variety.

[1] The quotations are from Schützenberger, on Fermentation.

Other varieties of these organisms are as follows:

Saccharomyces Ellipsoideus (Rees), Saccharomyces Pastorianus, S. Exiguus, S. Conglomeratus, S. Reesii, S. Mycoderma.

These are all species of the same genus and differ only in minor points. The *Ellipsoideus* and *Pastorianus* are possibly identical and are peculiarly adapted for wine fermentation.

FIG. 100. *e—Saccharomyces Ellipsoideus.* Alcoholic ferment of wine and juices of fruits.
f—The same developing spores. The cells are .000118 × .000098 of an *inch* in size.

The *Exiguus* occurs in the juice of fermented fruits.

The *Conglomeratus* is found in the must of wine near the end of fermentation.

The *Reesii* is found in the must of red wine. It has cells of peculiar elongated shape.

The *Mycoderma* appears in alcoholic liquids exposed to the air after the fermentation has become languid. It grows rapidly, covering the surface of the liquid with a thin whitish or yellowish pellicle. Engle estimated that one cell would in 48 hours produce 35,378 cells. The cells are variously shaped—ovoid, ellipsoidal and cylindrical, with rounded extremities.

FIG. 101. Different forms taken by *Saccharomyces Mycoderma.*

It occurs in all fermentations exposed to the air. Some suppose it to be modified from the beer yeast. It differs greatly according to treatment and takes different forms. It is competent to produce 35,378 cells from *one* in 48 hours.

The *Apiculated ferment* (*Carpozyma*) does not belong to the genus Saccharomyces. It is the most abundant alcoholic ferment. It is on all kinds of fruit, especially berries and stone fruit, and in most musts of wine. This variety has a small nib, or little apex, at the end of the cell.

"According to Engel, the apiculate ferment is a *Protomyces*, a fungus of the *Ascomycetes* family, without a mycelium. Its thecæ are spherical, covered with a perithecа, and are hibernating. The development of the spores is very slow and the spores numerous."

"The *Mucor Mucedo* and the *Mucor Racemosus* possess the property, when immersed in a solution of sugar and protected from the access of oxygen, of transforming or dividing their mycelium into joints having the form of balls. These balls are multiplied by budding and excite alcoholic fermentation in sugar as long as they are placed under these *abnormal* conditions."

"We see, in fact, the *Mucor Racemosus completely change* its mode

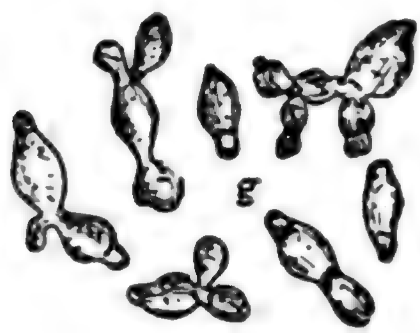


FIG. 102.

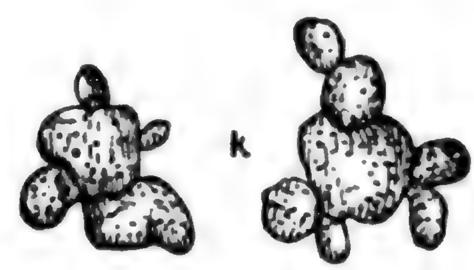


FIG. 103.

Fig. 102. *g—Carpozyma* or *Apiculated* ferment—the most abundant alcoholic ferment; met with on all kinds of fruit, especially on berries and stone fruits, and most wines in process of fermentation. Also, sometimes in beer. Magified six hundred diameters. The longest way they are 000236 of an inch, and one-half that the short diameter.

Fig. 103. *k—Mucor racemosus*—a fungus converted into an alcoholic ferment and taking on a new form.

of reproduction when it is placed without access of oxygen in a saccharine medium. Analogous facts are known to be produced in the case of other organisms."

This goes to show the modifying power of the environment over organizations, greater—as in this case—where the organism is simple, but extending, as we know, to the highest types of vegetable and animal life.

"These various kinds of ferments have been found not only in the must derived from fruits, but also on the surface of their pericarps, to which they remain fixed in a state of repose until by the concurrence of suitable circumstances they are placed in contact with the saccacharine fluid contained in the cell. From this moment they begin to develop by buds and set up at the same time alcoholic fermentation."

(*Must* is fresh pressed unfermented juice of fruit or fresh juice of malt.) Some of these ferments propagate by alternate generations. First, pseudospores are produced; these produce the true zoospores, and these in turn develop the cells. In this they imitate certain fungi, and also certain animal forms.

The action of the ferment on any liquid containing sugar results in the decomposition of the saccharine matter, chiefly into two substances; viz., alcohol and carbonic acid gas (or carbon dioxide). There are also other substances obtained at the same time in limited quantity; viz., glycerine, succinic acid, and acetic acid.

Of the acetic acid there is, according to some, usually five per cent. of the original quantity of the sugar, provided the fermentation is stopped as soon as the sugar is all transformed. Otherwise the quantity is increased, a part of the yeast itself, perhaps, being converted into the acid. Other acids are also apt to result, as Lactic acid, but when that happens it is due to another ferment which may get into the liquid from the air.

According to Pasteur, 100 parts of cane sugar, which corresponds to 105.26 parts of grape sugar, yields in consequence of fermentation:

Alcohol	51.11	
Carbon Dioxide	49.42	
Succinic Acid	.67	
Glycerine	3.16	
Matter united with ferment	.90	105.26

The first operation which beer yeast performs on cane sugar is to "alter it" by separating it into two isomeric parts called glucose and levulose This is affected by the zymase accompanying the yeast. Of it we shall hear again. Cane sugar, or saccharose, turns polarized light to the right. After alteration into the two parts, which are of equal weight; while they remain together the rotary polarization is to the left 25°. The rotary twist in the glucose alone is to the right with a power expressed by $+57.8°$, from which it is also called *dextrose*. While the other sugar, called *levulose*, when alone has a *left* polarization expressed by $-106°$ (hence *its* name). (For Polarization, see Chap. 41) The chemical formula of these sugars is thus expressed:

$$\underset{\text{Saccharose.}}{C_{12}H_{22}O_{11}} + \underset{\text{Water.}}{H_2O} = \underset{\text{Glucose.}}{C_6H_{12}O_6} + \underset{\text{Levulose.}}{C_6H_{12}O_6}$$

The addition of the molecule of water to the molecule of saccharose, forms a molecule composed of atoms, even in number, of each of the elements concerned, so that it is possible to split it into two parts, each containing the same elements in equal amount; Saccharose, after the water is added, having this formula: $C_{12}H_{24}O_{12}$. When split the two resulting molecules have the same formula $C_6H_{12}O_6$. The chemical analysis of these two then would make them precisely alike. But when looked at through polarized light they are proved to be *mechanically* different.

This separation, or alteration, is necessary before the further disintegration into alcohol and carbon dioxide can be effected by the ferment. The alteration can, however, be accomplished by other means—by simply boiling the cane sugar dissolved in water, or by the use of acids, or by exposing it to the light, or even by the mere pulverizing of the sugar.

Glucose (grape sugar or starch sugar), *levulose* (same as the sugar of acid fruits), *maltose*, or the sugar of malt formed by the action of diastase on dextrine, and *lactose*, or sugar derived from sugar of milk (lactine), by the action of acids; all have the same formula: $C_6H_{12}O_6$. They all act almost exactly alike in the presence of the ferments—splitting up into alcohol and carbon dioxide without undergoing any previous transformation. "The rotary power of a solution of glucose diminishes in proportion to the quantity of alcohol produced."

"Glucose mixed with levulose ferments sooner than the latter does by itself." The glucose disappears before the levulose, which last of all undergoes alcoholic decomposition. Dubrunfant has given this phenomenon the name of *elective fermentation*. The sugars whose composition is represented by the same formula as cane sugar ($C_{12}H_{22}O_{11}$), can be fermented only on condition of being first *hydrated*, that is, having a molecule of water, H_2O, added chemically to each molecule of sugar. This may be accomplished as above stated, by an acid, or light, or water alone, or the action of the ferment. Glucose crystallizes while levulose remains uncrystallizable.

Meletizose, melitose and lactine, or sugar of milk, like cane sugar, must be hydrated before fermentation can proceed. Only half of melitose "is decomposed into alcohol and carbon dioxide, the other is transformed into a compound, isomeric with glucose; namely, *eucalin*, which is not fermentable." "All bodies capable of producing glucose and its congeners by hydration, belong to the class of indirectly fermentable substances, such as starch, dextrine, gum, glycogen, and the various glucosides which are found in vegetable tissues." (Schützenberger, 33.) It is necessary that the ferment be in direct and immediate contact with the elements to be fermented in order that the action

may go on. Dumas proved, "that saccharine liquids are not influenced by ferment through even the shortest columns of liquid, or the thinnest membranes;" and that sonorous vibrations have no influence on fermentation. Many experiments have been made to imitate organic fermentation by chemical action without success. Electricity from a machine or an inductive coil of the galvanic battery is without effect on the movement. It is slower in the dark and slower in a vacuum, but will go on in either. It does not, therefore, require free oxygen, or oxygen as contained in air.

The chemical composition of the yeast plant differs under different circumstances. One analysis of surface yeast, which may be given as a specimen, is as follows: Carbon 49.9, Hydrogen 6.6, Nitrogen 12.1, Oxygen 31.4, Ashes 2.5. Analysis of the ash shows Phosphoric Acid 53.9, Potassium 39.8, Magnesia 6.0, Lime 1.0. Yeast is similar in composition to the cells of larger plants and of fungi, except that it is richer in nitrogen.

If fresh yeast be diffused in arterial red blood, or hæmaglobin saturated with oxygen, the tint will change rapidly from red to dark blue or black. "A simple agitation of the blood with air is sufficient to restore its ruddy color; then the phenomena of deoxidation recommence. The same experiment may be repeated a great number of times, especially with fresh and washed yeast."

In this case the yeast takes the oxygen from the blood (instead of from sugar), and the air restores it.

This experiment exactly imitates the process by which the blood as it circulates in the animal body is oxidized and deoxidized. The cells of the different tissues, muscular, areolar, epithelial, nervous, glandular, &c., act just like the yeast in absorbing the oxygen from the plasm of the blood to which it is diffused from the red globules. On the return of the blood to the lungs, the oxygen of the air passes through the walls of the air chambers and again enters and oxidizes the blood.

To make the experiment with the yeast a complete imitation of this process, red blood was made to pass through tubes composed of gold-beater's skin partly immersed in a solution containing yeast. The yeast cells absorbed the oxygen from the blood *through* the *skin*, thus turning the blood black. This process constitutes respiration, and it is shown that the respiration of yeast has a vigor superior to that of a cold-blooded animal like a fish.

When yeast is kept in a damp state without nourishment, experiments show that it lives at the expense of growing poor. That is, it consumes its own tissues like a starving animal living on its own fat.

When a considerable amount of yeast is set to ferment a small amount of sugar, after all the sugar is consumed the yeast continues "to react on its tissues and its hydrocarbons with extraordinary energy and rapidity, proceeding more and more slowly as the process goes on." This will happen also if merely water be mixed with the yeast, the vital activity continuing, and carbonic dioxide and alcohol being made at the expense of the substance of the organism itself. If 100 parts of yeast be dried it will be reduced to 30 parts, of which 22 parts constitute the cells of the organism and cannot be dissolved, while 8 parts are soluble and can be washed out. But if the same yeast be kept in a warm place in the form of a damp paste, for a couple of days, the soluble matter will be found to have doubled, its quantity having increased obviously at the expense of the organized cells of the yeast. This soluble matter contains a variety of substances, among which, it is extremely important to observe, is *Zymase*, a *ferment*, a *soluble* ferment, which accompanies the yeast and to which some of the most important phenomena

are due. We shall hear a good deal more of it. The substances extracted from the soluble debris of the yeast are similar to those obtained from animal tissues.

Yeast subjected to the process mentioned above is really digested by its ferment. Similar action resulting in similar products is obtained by placing warm, diluted sulphuric acid, or such alkalies as potash and barytes, in contact with proteids, gluten, albumen, &c., under certain conditions; a fact which, to my mind, proves the ultimate identity between, or, at least, common parentage of, chemical and vital processes.

Yeast, like other organic bodies, is subject to the effects of poisons, some of which act by coagulating the albumen and thus disorganizing the tissues. Among these are nitrate of silver, chlorine, iodine, soluble iron, tannin, creosote, chloroform, alcohol when above 20 per cent., &c. Yeast is always acid, and if the acidity be neutralized by lime water it will soon reappear.

The action of the fungus mucors in a fermentable solution is similar to that of the saccharomyces family. They grow at the expense of the infusion and promote alcoholic fermentation, though not with the same facility. The *mucor racemosus* produces 100 parts of alcohol to 123.1 of carbonic acid, while the ordinary yeast produces 100 parts alcohol to 96.3 carbon dioxide, which shows the mucor to be a more vigorous eater of carbon (sugar) for the work it does.

When growing on horse manure the mucor produces, from a spreading mycelium, numerous strong filaments the thickness of a hair, on the top of each of which a little round head is developed, which becomes the bearer of spores. But if these spores are sown in a fermentable solution their mode of life undergoes a radical change. "Either short germinating utricles shoot forth, which soon form themselves into rows of gemules, or the spores swell to large round bladders filled with protoplasm and shoot forth on various parts of their surface innumerable protuberances which, fixing themselves with a narrow basis, soon become round vesiculate cells, and on which the same kind of sprouts which caused their production are repeated—formations which remind us of the fungus of fermentation called globular yeast." (Cooke.) A number of fungoid and parasitic organisms will live in a fermentable fluid in which, however, they do not set up *alcoholic* fermentation, which shows, I think, that they are not associated with a *zymase*, or ferment of the right genus.

To sum up, in relation to yeast, its congeners and imitators: They are complete organisms having everything within themselves necessary to lead a parasitic existence, like an animal or vegetable parasitic cell. They are accompanied, in some if not all cases, by an accessory ferment, *zymase*, which assists them in the digestion of insoluble food. They respire by the absorption, from the solution in which they live, of oxygen, which they exhale with the carbon of their own tissues, forming carbonic dioxide, $C\ O_2$. Yeast sets up alcoholic fermentation in a solution of pure sugar in the absence of all trace of (free) oxygen, but without developing; that is, the yeast, or its zymase, does the work of splitting the sugar without growing itself.

A molecule of glucose being $C_6 H_{12} O_6$, if we conceived it being halved, each half molecule will be $C_3 H_6 O_3$. (That is also a molecule of lactic acid. They are therefore isomeric.) If from this a molecule of carbonic acid be taken; viz., $C O_2$, there will be left $C_2 H_6 O$, which is a molecule of common (or Ethylic) alcohol. Such a split evidently occurs in fermentation.

After glucose and cane sugar have been "altered," they are liable to a fermentation called *Viscous* or *Mannitic.* It transforms them into *carbonic dioxide, mannite* and *gum.* This sort of fermentation occurs in certain wines, in the sugary juices of plants, such as beets, carrots, onions, &c., and in solutions containing sugar and nitrogenous matter. The organisms concerned in this fermentation are small globules united together, the diameter of which varies from .0012 mm. (or .000047 of an inch) to .0014 mm. (or .000055 of an inch). (See Fig. 104, *l.*)

FIG. 104.

FIG. 104.—*l.*—*Viscous* ferment of wine. *m.*—*Lactic* ferment. *n.*—*Vinegar* ferment. (*Mycoderma Aceti.*)

This ferment sown in 100 parts dissolved sugar give Mannite 51.09, Gum 45.48, Carbonic dioxide 6.18.

Lactic Fermentation.

This consists in the transformation of certain sugars, as sugar of milk and grape sugar, into an acid, sirupy and soluble in water, called lactic acid. A molecule of lactic acid is only a half molecule of sugar and the process appears to be simply the splitting of the molecule—thus:

$$C^6 H^{12} O^6 \quad = \quad 2\, C^3 H^6 O^3$$

Sugar—1 molecule. Lactic acid—2 molecules.

Lactic acid exists in sour skimmed milk, the water of fermentation of peas and French beans, in the sour water of baker's yeast, in the sour water of starch manufacturers, and in sour kraut.

Lactic fermentation requires the presence of nitrogenous albuminous matter in process of decomposition. A mass of lactic ferment germs has much the appearance of ordinary yeast drained of water and pressed. (See Fig. 104, *m.*) It is rather viscid and of a gray color. Lactic fermentation sets itself up spontaneously in the proper medium and is more rapid often than alcoholic fermentation. Best temperature is 35° C. (95° F.) Lactic ferment often occurs along side of alcoholic in the same mixture, if it is favorable—sometimes occurs with beer yeast fermentation. In general, the sugars which are most easily fermented by alcoholic fermentation are the most difficult to lactic, and vice versa.

Mycoderma Aceti and *Mycoderma Vini* are two more fermenting organisms. Their work is done on alcohol, which they reduce to acetic acid and water. The first is developed on the surface of any aqueous liquid containing two per cent. alcohol, a little vinegar and traces of alkaline and alkaline earthy phosphates. The second appears in wine, making it acid and weak. The Mycoderma Aceti, a bacterium, grows over the surface of the solution forming a membrane by the interlacing of strings of cells. The cells are from $\frac{15}{10000}$ to $\frac{3}{1000}$ of a mm. in diameter. They are generally united in chains, and increase by cross divisions—fission. (See Fig. 104, *n.*)

In order that the change of alcohol of the liquid into vinegar should take place, this Mycoderma must be in contact with the air and the alcohol also. The alcohol is oxidized through the Mycoderma; that is, I should say, the plant first, or while imprisoning the alcohol in the fluid under its impervious film of cells—or *during* that operation rather—takes up the alcohol into its cells, where it comes into contact with the oxygen which the cell has absorbed from the air, and thus a new compound is formed of oxgen and alcohol; viz., acetic acid. The alcohol is first dehydrogenated, losing one-third of its hydrogen, when it is called *Aldehyde*, which then absorbs one atom of oxgen, forming acetic acid. Or it may form direct by adding two atoms of oxygen and losing the elements of a molecule of water.

The use of shavings in vinegar making was once supposed to furnish a catalytic medium on account of their porousness, but it was demonstrated by Pasteur that the shavings were covered with thin pellicles of mycoderma, to which the oxidation was due.

The action of the *Mycoderma Vini* is much the same as *Mycoderma Aceti*, but under its influence the combustion of the alcohol is complete, accompanied by the production of water and carbonic acid.

These ferments act in a manner analogous to yeast, carbon in the alcohol being to them the food that the carbon of the saccharine matters is to the yeast.

Another fermenting agency is called *Ammoniacal ferment.* Its cells are much smaller than those of beer yeast. They are spherical, without internal granulations, and appear to develop by budding. Their size is from $\frac{1}{5000}$ to $\frac{15}{10000}$ of a mm. This ferment acts upon Urea, which is the chief constituent of urine and the principal vehicle for the discharge of surplus nitrogen from the body. The urea is transformed into ammonium carbonate and carbonic dioxide.

The ferment also acts upon hippuric acid, a constituent of the urine of herbivorous mammals, separating it by hydration into benzoic acid and glycocol. The ferment does not previously exist in the urine, but is introduced by germs from the air, or it may be artificially sown. In some cases of disease it has been found in the bladder, supposed to have entered by way of the urethra. In one case it was thought to have been introduced by a catheter.

Butyric ferment is said to be an *animal* organism or infusorium of the genus *Vibrio.* They are little cylindrical rods rounded at the extremi-

ties, usually straight, either isolated or united in a chain of two to four joints or more. Their diameter is generally $\frac{2}{1000}$ of a mm., and length from $\frac{2}{1000}$ to $\frac{20}{1000}$ of mm.

They move by a sort of sliding motion, during which the body remains rigid or undulates slightly. They may spin round, balance themselves on one end and vibrate their extremities, and they often assume a bent position. They reproduce by fission. This organism lives and produces butyric fermentation if placed in a solution of sugar containing phosphates and ammoniacal salts. The result of its operations is *butyric acid*—$C_4H_8O_2$, which is the acid of rancid butter, and is also formed in many other organic compounds. In solutions of sugar the viscous, or mannitic ferment, is usually the first to appear, next the lactic, and lastly the butyric.

Putrefaction is another mode of fermentation, and, like the others, is promoted by an active organism. Putrescible substances are albuminoids and their allies, the constituents of vital organisms, which in the open air are usually unstable, because unless boiled they contain germs or become inoculated after a time from the air.

The active agent in putrefaction is the animal organism called *vibrio.* This vibrio, according to Pasteur and others, is killed by contact with free oxygen and can live only in a medium sheltered from air. In general, therefore, a solution does not show any signs of vibrios until the solution is covered with a film or pellicle formed by the action of *Bacteria* and *Monas crepusculum*, which require free oxygen and cannot live without it. Under this film the vibrios develop, and their growth and reproduction effect a separation of the albuminoid matters into more simple products, while the bacteria and mucors of the pellicle produce a still further splitting up of these products, reducing them to water, ammonia and carbonic acid.

Various opinions as to the intimate nature of fermentation have been entertained. Leibig believed it to be a species of decomposition which gradually spread by a sort of contagion from one particle to another of the solution in consequence of the ferment; a mechanical effect.

Berzelius and Mitscherlich thought fermentation to be a chemical action caused by the presence of the ferment as a mere catalytic agent. This view is disproved by the fact that the ferment greatly increases in quantity during the action, while in true catalysis the catalytic agent undergoes no change in itself, simply inducing change in the other elements.

Pasteur has expressed the opinion that fermentation goes along with and depends upon a vital act—the living and growing of the organism called *ferment*, and that it begins and ends with that vital act.

According to the opinion of others, "Yeast, like every living organism, shows phenomena of two kinds," assimilation and disassimilation. The first is the appropriation of food in nutrition, and is necessarily carried on simultaneously with the last, which is simply the rejection of the surplus and the waste. The various constituents of the solution, viz., sugar, nitrogenous compounds and mineral salts, penetrate the cases of the yeast cells by endosmose, undergo there suitable transformations and are, in part, converted into tissues to form the new buds and repair the old ones. The transformatory process converts the constituent elements, which are *not* appropriated to the growth, repair and reproduction of cells, into alcohol and carbonic dioxide, neither of which can be appropriated to the vital needs of the cells, and, consequently, are eliminated. The above is, in effect, the view of M. Bechamp.

As defined by Cornil and Babes, fermentations are "chemical processes undergone by substances broken up under the influence of organisms without chlorophyl, which develop and live in the liquid which ferments." This last definition does not contradict the preceding one, although it is noncommittal as to whether the constituents are broken up inside the cells or broken up outside of them by the abstraction of such molecules as the cells require for their use; which abstraction might be regarded as depriving the constituents of a bond necessary to their union—a sort of keystone which, being pulled out, allows the structure to fall into pieces, which thereupon employ their liberty in the formation of the new compounds, alcohol and carbonic dioxide.

Schützenberger's view is practically the same as that of Cornil and Babes. It may therefore be concluded that the general opinion is that yeast and other organic ferments are fungi of the simplest kind. Each cell constitutes an independent individual competent to put forth new cells by budding, or end its own existence in the production of two to four reproductive spores. Some years ago yeast was classed as a Torula, but as Torulæ never have spores that classification is abandoned, and yeast is placed in a family of its own, *Saccharomyces.* The cells of yeast and of fungi generally are, in many respects, similar in function and anatomical equivalence to those cells in plants which do not possess chlorophyl. All such cells, as we have seen, are, of necessity, parasitic and dependent, directly or indirectly, on the chlorophyl cells. These latter secure the carbon from the atmosphere and pass it into the parasitic cellular tissues of the plant in the shape of an insoluble starchy substance, or as saccharose. These substances are unassimilable in the tissues of the plants until they undergo alteration—the same process that is practiced on the saccharine elements in yeast fermentation as the first step in that fermentation. This alteration thus forms glucosides, that are assimilable. It is because of this unassimilability that these

starchy and saccharose matters can be accumulated in the cells of plants, as it is in the roots of the beet and maple, and in the stem of sugar cane and sorghum, &c., and in seeds. At a certain period the fermenting organism, zymase or diastase, becomes active and decomposes the starch into assimilable constituents, which are then consumed in building up the tissues of the plant.

CHAPTER XXVIII.

SOLUBLE FERMENTS—DIGESTION.

It was mentioned in the last chapter that the organized cells of yeast and other forms of organic ferments are accompanied by another principle, which is called a *zymase*. This word simply means a ferment, and is often used as a synonym of *diastase*. The yeast plant is called an organic ferment, and an insoluble ferment, while the zymase is a soluble ferment.

The yeast plant evidently owes its ability to live on sugar to its association with this *zymase*. In fact, not only the yeast plant but every other plant and animal requires the association and co-operation of a zymase, or perhaps more than one, in order to have the materials required for its growth and repair put in such shape that they can be assimilated, just as it is essential that the brickmaker, the quarryman, the sawmill man, &c., shall prepare materials for the bricklayer, the stone cutter and the carpenter to work into the several parts of a building.

The fermentations which take place in the animal body and which result in the splitting up of the food into such shapes that the pieces will fit the various tissues of the body, are spoken of under the general term *digestion*. Some of the processes of digestion may be imitated by the chemist in his laboratory.

Thus the hydration of starch, by which it is resolved into glucose and dextrine, and the further resolution of dextrine into maltose, all which is accomplished by the digestive ferment in the natural state, may also be performed by the chemist with *dilute sulphuric acid*. There is a ferment in the body which turns the fats of the food into soap. The soap maker does this, too, by boiling the fats with an alkali.

The following is a general list of food-producing substances upon which the zymases act in the ordinary processes of digestion.

1. *Proteids* (or albuminoids). Containing *Carbon*, *Hydrogen*, *Oxygen* and *Nitrogen*, and sometimes *Sulphur* and *Phosphorus*; *Gluten* of flour, vegetable fibrin, *Albumen* of the white of egg and blood serum; *Fibrin* of the blood; *Syntonin*, chief constituent of muscle and flesh; *Casein*, chief constituent of cheese; *Legumin*, vegetable casein; *Gelatin* from connective tissue, and *Chondrin* from cartilage.

2. *Fats.* Composed of *Carbon*, *Hydrogen* and *Oxygen* only, and containing more hydrogen than sufficient to form water if united with the oxgen which they possess. They include all *oils*, and *vegetable* and *animal fatty* matters.

3. *Amyloids*, or starchy substances composed of *Carbon*, *Hydrogen* and *Oxygen* only, but with hydrogen and oxygen in just the same proportion as they occur in water. *Starch*, *Dextrin*, *Sugar*, *Gum*, *Glycogen*—an animal starch formed in the liver.

In addition to the Proteids, Fats and Amyloids, which are derived from organized bodies, there are water, salts, earths, and some metals required, which are obtained either from organisms or from the mineral kingdom.

The composition of Proteid, or albuminoid substances—albumen, fibrin, casein, gluten, syntonin, legumin, &c.—is almost exactly the same for all, and they are probably isomeric, that is, composed of the same materials put together in molecules of different forms. Their constituents are as follows: Carbon, 53.5 parts; Hydrogen, 7.1; Nitrogen, 15.6; Oxygen, with some sulphur, 23.5, and small amounts of other minerals.

These food materials are all split up by the different sorts of soluble ferments.

Among the soluble ferments enlisted in the process of animal digestion are ptyalin, gastric juice, pepsin, pancreatic juice, &c., which will now be mentioned more in detail. They differ in their offices, having power to affect different kinds of food. As a rule, each has power to cause a split in some class of compounds.

Ptyalin is a ferment found in the saliva, a secretion which comes into the mouth chiefly from the salivary glands, of which there are four pairs in human anatomy; one pair just in front of the ears called the *parotid*, one pair in the floor of the mouth under the front part of the tongue called the *sublingual*, one pair back of the last, in a fold of the mucous membrane, called the *lingual*, and one pair on either side of these, called the *submaxillary*. The ducts of these all open into the mouth, and the glands, when stimulated by the action of mastication, pour in their secretions to be mingled with the food. The action of the ptyalin is to split starchy and saccharose matters—amyloids—separating them into glucoses.

The *Gastric Juice* is secreted by a number of small branching glands which open upon the surface of the mucous membrane which line the stomach. These are called *peptic glands.* The gastric juice is a thin fluid containing lactic or hydrochloric acid and a ferment called *pepsin*. *Pepsin* acts only on albuminoids, all of which it splits up and reduces to a pulp the consistency of pea soup, which is then called a *peptone*. In the process of this digestion the fibrin, and other albuminoids, are first reduced to *syntonin*, and afterwards, by prolonged digestion, into the peptone. A considerable part of the peptone is fit for assimilation by the tissues of the body without any further digestion, and, therefore, much of it is taken through the membranes of the stomach directly into the blood circulation. The parts of the food that have escaped chemical reduction by the ptyalin of the saliva or the pepsin of the gastric juice, will nevertheless be found to be dissolved by the gastric acids and by the mechanical movements of the stomach. The name given the food in this condition is *chyme*. After a time this chyme passes through the lower gate of the stomach, called the pylorus, into the upper part

of the small intestine, called the *duodenum.* Opening into the duodenum, not far from its middle, are two ducts, one from the liver and the other from the pancreas. When the chyme from the stomach is poured into the duodenum it is met by a fluid from each of these ducts. That from the liver is called the *bile* and the alkali contained in it neutralizes the acid of the chyme and permits the resumption of the fermentation of the starch and sugars, which, on account of acidity, is suspended in the stomach. The fluid from the pancreas contains, it is supposed, three several ferments. One of these has the property of ptyalin, of splitting up starch into glucoses, one has the quality of gastric juice, of disintegrating the albuminoids, and the third is an *emulsive ferment*, able to dissolve the *fatty* bodies, a process called saponification.

The action of the Emulsive ferment causes the mechanical division of the fats of the food, separating them into innumerable globules fit for absorption into the tissues. Milk is naturally in this state of preparedness for absorption, and it is believed by some to possess this same emulsive ferment by which this state is constantly brought about.

The process of emulsion in the duodenum is instantaneous. The action of the three pancreatic ferments upon the three general classes of food products converts them into a milky substance, in which are suspended a vast number of fatty particles. It is called chyle, and as it is crowded along the intestines it receives further contributions from little glands situated within the mucous membrane of the intestines. The secretion from these glands is called *intestinal juice*, and its functions are supposed to be similar to those of the pancreatic juice.

There are three sorts of glands in the small intestines. One set, called Lieberkühns, glands, consist of "fine capillary blind sacs, the openings of which are from $\frac{1}{360}$ to $\frac{1}{240}$ part of an inch in diameter, so closely packed over the whole of the small intestine as to give the mucous membrane a general sieve-like or perforated appearance." (Med. Dic.) These glands secrete the intestinal juice. Another set, called the solitary glands or follicles, are situated between the mucous and muscular coats of the intestine. They are also sometimes called Brunner's glands, though the latter name is usually confined to similar ones situated in the stomach and duodenum. Their business is said to be the secretion of mucus. The third set are found mostly in the lower part of the small intestine—the ileum. They are called *Peyers* glands. As they are clustered together like a honeycomb they are sometimes denominated "patches." They are small cells or bags lying under the mucous or villous coat of the intestine, and are without ducts, their secretions, whatever they are, passing through the pores of the membrane. Their functions are not well known. These "patches" and the solitary follicles become involved in typhoid fever, undergoing ulceration in that disease.

Even in the large intestine and in the rectum itself, there is reason to believe, still further digestion takes place, or at any rate from these parts of the intestinal tube such digested matters as may still remain in the food, are absorbed and carried into the blood. Food injected into the rectum will be absorbed into the circulation and afford effectual nourishment to the tissues. But the greater part of the absorption of the nutritive matters from the reduced and fermented food takes place through special organs in the mucous membrane of the small intestines.

This membrane is full of transverse corrugations or folds by which its surface is increased, and upon this surface are set numerous small projections called *villi*, each of which contains a vein and an artery from the general system, and also the blind end of a lacteal vessel which connects with the general Lymphatic system. The chyle is in large part absorbed by these lacteal vessels—perhaps in part by the blood vessels themselves—and thus directly or indirectly gets into the circulation.

The ferments are in part re-absorbed and soon find their way back to the organs from which they were derived, but in part they remain with the products of their fermentation, and pass with them into the circulation and follow it to distant parts of the system. Thus pepsin has been found in the blood, in the muscles, and in the urine.

In like manner the Emulsion, after penetrating the lacteal vessels, continues to experience the effects of the ferment, which undoubtedly goes along with it, producing the so-called saponification even in the tissues of the system. This "saponification" consists of "resolution of trimargarin, triolein, tristearin, &c., by hydration into glycerine and fatty acids. (*Schutzenberger.*)

Trioline + water is split into Glycerine + Oleic Acid.

Tristearine + water is split into Glycerine + Stearic Acid.

Tributerine + water is split into Glycerine + Butyric Acid.

The emulsive ferment possesses the property of casein, of being precipitated in the cold by magnesium sulphate. It is coagulated by heat. The effects of the emulsive ferment can be obtained from the extract of the *pancreatic gland* itself.

There are said to be three substances concerned in the production of fibrin. These are *fibrinogen*, which exists in the blood; *paraglobulin*, a fibrinoplastic substance which is formed by the disintegration of white blood corpuscles and other cells; and third, is the *fibrin-ferment*, also formed from white blood corpuscles and perhaps other cells. The coagulum, or fibrin, is formed by the union of the first two, which takes place in the presence of the *fibrin ferment*. The latter does not enter into the combination itself, but enables the other two to do so by causing some sort of chemical action, probably a preliminary split in one or both, enabling the parts to enter into a new combination. (*Flint.*)

The liver is an organ competent to form *glycogen* from the blood passing through it. And its tissues are themselves apparently composed of it in part, at least. Glycogen is an amyloid substance resembling

"starch, dextrine and gum in chemical compositions, consisting as it does of carbon united with hydrogen and oxygen, the latter being in the same proportions as in water." If the liver be extracted from an animal, and all the blood washed out, and it be then left to itself in a moderate temperature, it will soon be found to contain a quantity of sugar. Moreover, glycogen can be extracted from such a liver, by proper methods. It is also found to contain or secrete a *ferment* competent to split up this glycogen into soluble glucoses. (*See Huxley and Youman's Physiology.*) The ferments possessed by the animal organism are, no doubt, the result of a transfer or migration from the vegetable kingdom—as is the animal himself.

Some more of the ferments found in plants may be mentioned. The *Emulsin* of almonds is an exceedingly vigorous ferment. It is also called *synaptase* and is extracted from both bitter and sweet almonds. The bitter almonds also contain, in separate cells, a product called *amygdalin.* This may be extracted in the shape of a crystalline powder. If a weak solution of this powder be made, the emulsin has power to split it up into oil of bitter almonds and hydrocyanic acid (or prussic acid), a deadly poison. The same may be obtained from *cherry, laurel*, leaves of *peach tree*, kernels of *fruit, apple seeds*, &c.

A like emulsive ferment is found with plants having oleaginous seeds. If such seeds are steeped in water the extract is split into glycerine and a fatty acid.

There is a ferment contained in Mustard, called *Myrosin.* It resolves a substance, which is present in black mustard and is called potassium myronate, into glucose and two or three other compounds. There is a ferment in Madder, called *Erythrozyme.* There is a ferment in *Buckthorne.* In the bark of the Aspen there is a glucoside or starchy substance called populin, and in the bark of the Phillyrea latifolia, an evergreen shrub of Southern Europe, there is another called phillyrin. The glucose is separated from either of these by the lactic ferment.

In gall nuts there is a ferment which operates upon an infusion of the nuts, if left to itself, and causes the *tannin* to be resolved into glucose, and gallic and ellagic acids.

Pectose is accompanied by a soluble ferment which transforms pectose and pectin into pectic and metapectic acids, successively. It occurs in various vegetables and fruits and helps the transformation of their natural juices into jellies.

The soluble ferments all contain carbon, hydrogen, nitrogen and oxygen. But their reactions are different from those of the albuminoid substances they are associated with. The soluble ferment is not precipitated with tannin and corrosive sublimate, nor colored by iodine and nitric acid as these substances are. These ferments are associated with living organisms, but their actions are their own and independent of that of the organism, and they can be separated from it.

Soluble indirect ferments, or zymases, when dry are amorphous, colorless, pulverulent

matter. They are usually made into precipitates from their aqueous solutions by alcohol, corrosive sublimate, and neutral or basic lead acetate. They can be again made to restore their specific properties by decomposition by sulphurretted hydrogen. They are almost always accompanied by more or less albuminoid matter. "If the sublimate precipitates them from liquids extracted from the organism, it is rather by mechanical action than by the fact of a chemical combination," for "soluble ferments, when deprived of albuminous principles, are not precipitated by the sublimate."

Pure pepsin is extracted from natural or artificial gastric juice. It is obtained from the mucous membrane of the stomach, which is cut up and placed in water containing 5 per cent. of phosphoric acid, at a temperature of 95° F. This is precipitated and further treated chemically.

Pure ptyalin, salivary diastase, is obtained from saliva.

There are various methods employed by chemists for separating these ferments from the vegetable or animal organs which contain them. Von Wittich's method is to cut up the organ containing the ferment into pieces, clear it from blood, if necessary, and leave it under alcohol for twenty-four hours. It is then "dried in the air, pulverized and sifted. The powder is diffused in glycerine and this glycerine solution is precipitated by alcohol. By repeating this operation several times, solution in glycerine and precipitation by alcohol, an active powder, free from albuminoid matter, is obtained."

The ferment of plants, which has the power to turn starch into dextrine and glucose, usually goes by the name of Diastase. An active artificial diastase, or, rather, a preparation of a natural diastase, is made in the following manner: One part of *germinated barley* is powdered and added to two parts of water. After steeping for an hour the water is squeezed out and to it is added an equal quantity of alcohol at 176° F. It is then filtered, and to the filtered liquid an equal volume of alcohol is again added. Then it is filtered a second time, and the precipitate remaining on the paper filter this time is dried slowly and the paper is ready to be used as a ferment, and can be kept for any length of time.

This diastase of germinated barley is practically identical with the salivary ferment *ptyalin*. Either of these ferments, and several others, are competent to cause the alteration of starch, sugar, the glycogen matter of animal tissues, &c., in a few minutes by hydration. The process of the change in starch is shown thus:

$$\begin{array}{lcl} 2\,(C_6\,H_{10}\,O_5) + H_2\,O &=& C_6\,H_{10}\,O_5 + C_6\,H_{12}\,O_6 \\ \text{2 Starch} \quad + \text{Water} &=& \text{Dextrine} + \text{Glucose.} \end{array}$$

That is, the diastase causes two molecules of starch to take up a molecule of water, and then fall apart into a dextrine molecule *isomeric* with the original starch molecules, and a glucose molecule the same as a starch molecule with the addition of the molecule of water. It is evident that the effect here of the diastase is to rearrange the atoms composing these molecules so as to give them new shapes and new polarities. In short, the action is purely magnetic.

If the diastase were associated with yeast in the above action on the starch, the dextrine molecule would become glucose also, and all of them would by the action of the yeast become alcohol and carbonic dioxide.

The diastasic ferment in the pancreatic juice is very powerful, being practically instantaneous.

The presence of the ferment in germinating seeds has been mentioned. It shows itself in the spring in the potato, dissolving the starch. The ferment follows the formation of glycogen in the liver as mentioned above.

But there is a curious exception in the case of animals that undergo metamorphoses. The larva of the house fly is stuffed full of starch or glycogen, which is not turned to sugar while the fly remains in that state. But when the fly passes from the larval to the chrysalis stage the ferment appears and the glycogen is dissolved and used up in the construction of new tissues. According to Bernard, something like this happens in the fœtal life of mammals. A time arrives when deposits of glycogen, which have previously been made, are required to promote rapid growth of certain parts, when this material is suddenly converted into sugar and used up.

The frog, something like the fly and the plant, appears to be influenced by the season in the secretion or activity of his diastase. This ferment exists in the blood in its veins during the spring and summer, so that if dextrine be injected into the veins it is turned to sugar; but if it be injected in winter, the dextrine will pass through the veins and be carried off in the urine without change.

The diastase has been found in the digestive tube of the silk worm by Balbini. In short, it is found in all animals and plants that use starchy substances for food; if it were not, such substances would not be food at all.

It thus appears that the vegetative economy of the human and other animal organisms includes as a necessary part of their machinery a number of vegetable ferments or zymases; the counterparts of which are to be found in various plants. Furthermore, the cells of many of the tissues themselves are able to disintegrate appropriate food stuff and select out of it what they need. Thus if meat be introduced into a subcutaneous wound it will become digested as in the stomach. But starch or cane sugar in the same locality would remain unchanged and pass through the blood and be eliminated as an excretion. The soluble ferments of vegetables become necessary to them because the sort of food prepared for them by the action of sunlight upon chlorophyl is the insoluble unassimilable starch. Furthermore, it is plain that a substance which could not be made soluble when wanted by the plant would not answer for its food in a climate where the active growth is

necessarily suspended half the year. During this suspension the food must be in a condition to escape being dissolved and wasted. So that starch is an essential sort of food for plants, and diastase is an essential sort of an agency for breaking it up when it is needed.

It would appear that the soluble ferments cannot be regarded as true organisms, although they are organic in their composition and always found in nature in association with organisms. As already mentioned, their action is imitated by various chemical agents—acids or alkalies. A small quantity of sulphuric acid will act to alter a great quantity of fermentable matter, and the acid will continue to act indefinitely without diminution. In like manner a small amount of the natural ferment can modify a vastly greater quantity of starch. According to experiments of Payen and Persoz, 2000 parts of starch can be altered and turned to sugar by one part of diastase, and if the glucose be removed as it is formed, the process may continue apparently indefinitely, although there appears to be a slight deterioration in the force of the diastase after prolonged service. The yeast plant, mucors and other parasitic organic ferments grow at the *expense* of the fermentable matters in which they act and which they alter, but it is not so with the diastases. Their presence merely is all that is required. This fact, together with the great rapidity of their action, often, as it is said, instantaneous, shows that the results they bring about are not due to their growth or consumption of a part of the materials. One diastase may be able to act upon several different sorts of glucosides or fermentable matters, producing quite different sets of results. Thus emulsin or synaptase, the ferment contained in almonds, acts upon amygdalin, resolving it into glucose, benzoyl hydride, and prussic acid ; it resolves salicin into glucose and saligenin ; helicin into glucose and salicylic hydride ; arbutin into glucose and hydroquinone ; phlorizin into glucose and phloretin ; esculin into glucose and esculetin ; daphnin into glucose and daphnetin ; and several others. The *origin* of the diastase appears to be in the permanent glandular organs of the plants or animals where it is found, and it is a manufactured product of such an organism. It further appears when manufactured, in some cases at least, to become incorporated in the tissues of the gland where it originates, so that to get the diastase we have only to chop up the gland. The use of the rennet stomach of a calf in curdling milk in cheese-making illustrates this, the organ itself possessing the diastase. The same is proved by the facts in relation to the conversion of glycogen into sugar in the liver, also by the preparation of diastase from germinated barley mentioned above.

The *manner* in which the diastase *acts* is not clear. But it seems tolerably certain that the diastase itself does not enter into combination

with the substance it appears to affect. It may, in the process of digestion, mingle with it and accompany it in its movements through parts of the organized body, but still it retains its identity and, in some cases, appears to return to the organ in which it originated. Since its effects cannot be attributed to giving up its own materials or to receiving any, they must be due in some way to *its mere presence.* And this, I think, is the fact.

The diastase is merely a *catalytic* agent inducing, by its influence, a union between a molecule of starch and a molecule of water, and I suppose it does this merely by modifying the *shape* of one or other of the molecules without otherwise changing the amount or kind of substance it contains. It is the same sort of phenomenon that occurs when sulphurous acid gas ($S\,O_2$) and air or oxygen are mixed together and then brought into contact with hot platinum sponge. Without loss or change to the sponge, the sulphurous acid gas is made to take up enough of the oxygen to form sulphuric acid ($S\,O_3$). Other substances, such as clay, pumice-stone, and the oxides of copper, chromium, and iron, will perform the same service as the platinum sponge in this case. Their mere presence causes the union.

Every particle or body of matter is subject to electrical movement or electrical tension, the manner, direction or position of which depends upon the polarities of the body, which in turn depend upon the relative position of its molecules and atoms. The introduction of any body into the environment of any other will disturb its electrical condition; and it may disturb it to the point of dissolution of the body, or it may cause such new arrangement of its component atoms as to give it new polarities and new affinities. This last is what appears to be done in the case of catalysis, and in the operation of the diastase. The production of the ferment in plants and in some cold-blooded animals, takes place at certain seasons only, and this proves that it is regulated in some way by influences outside of the organism. Evidently the rise in temperature which takes place in spring furnishes the force by which the diastasic molecule is shaped in, and detached from, its mother gland.

In the warm-blooded animals which do not hibernate, and in the perpetually growing plants of the tropics, heat is always present and the ferment is always in stock.

The diastase may be regarded as a cross between a mineral compound and an organism. It is not a full fledged organism because it has not the power of reproduction or self perpetuation. There are many qualities in common between it and the yeast plant which always has it in companionship, and there are some contrasts. The organic ferment, by its organization, appears to be able to resist certain influences to which the diastase succumbs; for example, its activity is not prohibited by

citric acid, tartaric acid or borax, while either of these will put a stop to the operations of a diastase. On the other hand, compressed oxygen, which will, in the course of time, destroy the organic ferment, does not hurt the diastase. Prussic acid, the mercurial salts, alcohol, ether, chloroform, and the essences of cloves, turpentine, lemon, mustard, &c., will prevent the action of the organic ferment, while they do not disturb that of the soluble diastase.

The organic ferment eats and grows. It cannot do this until its friend the diastase has broken up the starchy matters containing its food. Let the two ferments get into an organic compound; the diastase at once splits up by hydration the insoluble starches. After this the various kinds of organic ferments get in their work, some in one kind of compound and some in another; those most available being, in general, the glucoses, albuminoid matters, alcohol, urea, and various acids, such as citric, malic, lactic, tartaric, &c.

Watts gives the name "*Invertin*" to the soluble ferment accompanying yeast—saccharomyces, and says that it is manufactured by the cells of the yeast. In like manner, he says, Bacteria convert starch into a sugar capable of reducing cupric oxide by means of a *ferment* which they secrete. This ferment is soluble and can be precipitated by alcohol. It acts on starch in the absence of oxygen and is secreted by Bacteria in a neutral starch solution. It does not possess peptonizing properties, but the same Bacteria can, under proper conditions, produce a ferment that will. (Watts' Chem. Dictionary, 2–540.)

From a physical standpoint it is inaccurate to speak of a soluble ferment as amorphous, for its ultimate particles, either as cells or molecules, must certainly possess a definite characteristic molecular or atomic constitution and form, giving position to its magnetic poles and direction to its currents. And it is only when its disintegration has gone so far as to subvert this ultimate constitution of its particles, that the ferment is dead, amorphous and functionless. Mere mechanical grinding up cannot accomplish such disintegration, as it does in the case of the organic ferment; it can be done only through chemical or other dynamic agencies which destroy the molecule by the seduction or dispersion of its atoms.

CHAPTER XXIX.

REPRODUCTION OF VEGETAL CELLS.

There are various opinions as to the manner in which life originates or comes into view in a mass of apparently dead matter. Examine any summer puddle of a few days' duration and it will be found teeming with lively and active organisms. The question that has been a subject

of much discussion and experiment is, do these live organisms arise from matter previously non-vital, or have they merely inherited their vital functions from organized predecessors? If we affirm the latter alternative it means merely that we have not yet reached the ground upon which the question of the origin of life is to be settled and must look further. Famous scientists have worked at this problem. Their method of procedure has usually been to seclude from contamination with germs which might be in the *air*, mineral and organic solutions and infusions which were previously boiled to kill any germs *they* might contain. I shall quote freely from Prof. Tyndall's work on "Floating Matter in the Air," in which he discusses the question. He takes the ground that no infusion or solution of organic or mineral matters has yet been made in which animal or plant life will originate, provided all living germs have been excluded therefrom, even though such infusion were competent to nourish such organisms when sown in it. He concluded that boiling five hours would render such infusion forever incompetent to originate life. He may be correct, but the difficulty of proving a negative is so great that I doubt if his proofs can be regarded as conclusive. But whether he has proved it or not the *point* is by no means a conclusive one, one way or another. We are morally certain that the *vegetable* kingdom originated from the *mineral*—the *important* question is *how*. Suppose it to be proved that life will not originate from a boiled hay infusion; that is something to be sure, but not much to the point. Suppose the contrary be proved, still *the* question remains unanswered, for we know very well that nature did not have a hay infusion to work with before there was any life. In the experiments of Pasteur, Tyndall and others, in which they boiled the infusions with which they worked, in order to destroy adventitious germs, it is evident that they also destroyed by that process whatever organization there might be in the protoplasm of the infusion. That is to say, their precautions insured them not only against the germination of any spores, seeds or germs, either from the air or in the infusion, but it stopped any possible development of life which might otherwise arise as a consequence of the *organization* of the protoplasm. The protoplasm of the infusion may be compared to a watch that has run down. If the works are not injured, *when force* is *put into* the watch again by winding it up, it will again show signs of life. So the protoplasm is a machine—or many machines together—and as long as the cells are uninjured they are liable to the motion we call vitality when the force is applied to them. But if before winding the watch we pull out the main-spring, hair-spring and two or three wheels, we render it tolerably certain that no application of force will give any sort of vital action to the watch; and in like manner the destruction of the organization of the protoplasm

totally disqualifies it from being operated upon in such a way as to show vital reactions. It is true that the intention of the experimenters was to thoroughly disorganize the infusion so as to see whether it would become reorganized again. Nothing can be more obvious than that if they had supplied to their infusions the necessary force under the necessary conditions, they would have effected their reorganization into vital organisms. If they failed in this result it is simply evidence that they failed to supply the conditions. It is by no means certain that if the conditions were thoroughly known it would be possible to fill them. Something more than the mere aggregation of the materials is essential. An organism does not construct itself any more than a house does. A drop of water constitutes the material of a crystal of snow; but a drop of water, carefully boiled and then sealed up in an air-tight flask, will never make itself into a crystal of snow. Consider that an organism is a machine built up by energies outside of itself, then grant that we have a general idea of what these energies are, still we must admit that the chances of being able to marshall them at the right time, in the right place, in the right proportion, strength and sequence, are, to say the least, rather slim. Knowing that it takes nothing more to hatch a hen's egg than a temperature of so many degrees, applied steadily for three weeks, the force is so simple anyone can fill the condition. But it would be a very different problem if we were to boil the egg, as a preliminary step. The conditions of life among the protozoa are not so complicated as among beings of higher organization, and it does not antecedently appear so very improbable that experimenters might sometime stumble upon the combination of materials and energies necessary to the production of a single celled organism. Some experimenters, among whom is Dr. Bastian, claim that this has already been done.

If it has not been done, it is only, as I said before, because *all* the conditions have not been supplied, and it is only a question of time when they will be. The deficiency, if there be any, is probably not in the materials required, but in the application of the *polar energy* necessary to arrange them in the positions essential to fuse them into a coherent organism.

It is not essential to my purpose to assume the question to be decided one way or another. But the discussion has brought out some interesting and important facts which it will be useful to call attention to.*

The cells of fruit are competent to act in the same way as the cells of the Torula, Saccharomyces and other ferments. The condition required being that the cells be alive, which, I believe, means only that they be whole and uninjured. "The yeast plant is an assemblage of living cells;

(* The quotations following are from Prof. Tyndall's work cited above unless otherwise specified.)

but so at bottom, as shown by Schleiden and Schwann, are all living organisms. Cherries, apples, peaches, pears, plums and grapes, for example, are composed of cells, each of which is a living unit." "In 1821, the celebrated French chemist, Berard, established the important fact that all ripening fruits exposed to the free atmosphere absorb the oxygen of the atmosphere, and liberate an approximately equal volume of carbonic acid. He also found that when ripe fruits are placed in a confined atmosphere, the oxygen of the atmosphere was first absorbed and an equal volume of carbonic acid given out. But the process did not end here. After the oxygen had vanished, carbonic acid in considerable quantities continued to be exhaled by the fruits, which at the same time lost a portion of their sugar, becoming more acid to the taste, though the absolute quantity of the acid was not augmented." Here is a process which imitates fermentation to this extent, that the cells of the fruit respire, as do the cells of yeast, but being at first in contact with the atmosphere they get their oxygen from it, and exhale it with carbon derived from their own decaying tissues. When the amount of this free oxygen, or oxygen from the open air, is limited by the fruit being shut up in some close receptacle, as, for example, an air-tight barrel, the cells will proceed to breathe up all the free oxygen in the barrel, replacing it with carbonic acid; and when it is all gone they will not die but they will continue their respiration by extracting the oxygen in the sugar of the juices by which they are surrounded in the fruit. This last operation is the same as that performed by the yeast plant from the first. It gets its oxygen from the sugar in the wort and does not breathe the free oxygen at all. It was finally proved by Lechartier and Bellamy that the last action of fruit cells, after deprivation of free oxygen, produced alcohol. Pasteur confirmed this discovery by further experiments. He placed grapes in an atmosphere of carbonic acid, "and they produced alcohol and carbonic acid by the continued life of their own cells." Then he tried it on plums. Twenty-four were placed under a bell-jar filled with carbonic acid, and twenty-four similar plums were placed outside the jar uncovered. "At the end of eight days he removed the plums from the jar and compared them with the others. The difference was extraordinary. The uncovered fruits had become soft, watery and very sweet; the others were firm and hard, their fleshy portions not being at all watery. They had moreover lost a considerable quantity of their sugar. They were afterwards bruised and the juice was distilled. It yielded six and a half grammes of *alcohol*, or one per cent. of the total weight of the plums. Neither in these plums nor in the grapes first experimented on by Pasteur could any trace of the ordinary alcoholic leaven be found. As previously proved by Lechartier and Bellamy, the fermentation was the work of the living

cells of the fruit itself after air had been denied to them. When, moreover, the cells were destroyed by bruising, no fermentation ensued. The fermentation was the correlative of a vital act and it ceased when life was extinguished. Ludersdorf was the first to show by this method that the yeast had acted not as Liebig had assumed in virtue of its *organic*, but in virtue of its *organized* character. He destroyed the cells of yeast by rubbing them on a ground glass plate, and found that with the destruction of the organism, though its chemical constituents remained, the power to act as a ferment totally disappeared.".

We thus perceive that the cells of fruit are alive in the same sense that the cells of yeast are, at least to the extent of breathing, and like yeast and certain other parasitic cells, can take the oxygen required for their respiration from a carbon compound when they cannot get it free. These cells are probably reproductive by fission or germination so long as nourishment is supplied to them, that is during the growth of the fruit. This is practically the principal mode of growth by both Torula and Saccharomyces, although this mode is supplemented in the latter by the power to form spores also, under proper conditions. If the cells of fruit or yeast be broken up by mechanical means, or by too much heat, they are killed and cease to breath or to grow and bud.

We are indebted to Prof. Tyndall's book for the description of the mode of making "That fiery and intoxicating spirit known in commerce as *Kirsch* or *Kirschwasser*."

A cask with a very large bung-hole is nearly filled with cherries. The bung-hole is closed tightly and the cherries left for fourteen days. At the end of this time the bung being removed, the air in the space above the cherries is found to be converted into carbonic acid gas. The contents of the cask are emptied into a copper still and evaporated by heat; the vapor passing through a cooled pipe and being condensed into the alcoholic liquor "Kirsch." No ferment is put into these cherries but they are expected to furnish their own ferment, and they always do.

The fermentation of wine is also automatic. The wine maker depends on the grape juice to furnish its own ferment, and has done so for 3,000 years without disappointment. In the fermentation of wine (and I suppose of the "Kirsch" too, though it is not definitely so stated) the Torula (or rather Saccharomyces) is invariably the active agent. In answering the question, where does it come from, Tyndall states on the authority of Pasteur, that "at the time of the vintage microscopic particles are observed adherent both to the outer surface of the grape and to the twigs which support the grape." Some of these seen through a microscope look like "organized cells." If they are brushed off and put into the pure inert juice of the grape they will produce fermentation in forty-eight hours, and "our familiar Torula is observed budding and

sprouting." He draws the inference that the adherent particles are the ferment. "The ferment of the grape clings like a parasite to the surface of the grape."

But how about beer? If the beer-wort is exposed to the air it "sooner or later ferments; but the chances are that the produce of that fermentation instead of being agreeable would be disgusting to the taste. By a rare accident we might get true alcoholic fermentation, but the odds *against* obtaining it would be *enormous.* Pure air acting upon a lifeless liquid will never provoke fermentation, but our ordinary air is the vehicle of numberless germs which act as ferments; when they fall into appropriate infusions, some of them produce acidity, some putrefaction. The germs of our yeast plant are also in the air but so *sparingly distributed* that an infusion like beer-wort exposed to the air is almost sure to be taken possession of by foreign organisms. In fact, the maladies of beer are wholly due to the admixture of these objectionable ferments whose forms and modes of nutrition differ materially from those of the true leaven."

Thus we understand Prof. Tyndall that the germs of the yeast plant are *scarce* in the air. Yet they are so abundant on the skins and stems of grapes that they invariably set up the true alcoholic fermentation. They evidently, then, must be far too numerous on the skins and stems of grapes to have been derived merely from the air; for we are to conclude that they are on *all* grapes; since fermentation will take place in all. If the supply comes to the grape from the air why not also to the beer-wort? Has the grape some peculiar attraction for these parasites? Are these germs just as thick on every other object as upon the grapes? If not, why not? It is decidedly improbable that they are on all objects in such abundance as they appear to be on the grapes. There are many localities in which a vineyard, an acre in extent, may be surrounded by fifty square miles destitute of vines. Must we suppose all such districts to be thickly sowed year after year with yeast germs which never sprout but are nipped by the frosts of every autumn? Whence comes this annual supply in such enormous and wasteful abundance? Bacteria germs we might reasonably expect to be tolerably plentiful, for they would become exposed to the winds on the drying margins of every ditch and pond during the summer months. But the yeast plant is far more dainty. It does not live in ponds and ditches nor flourish in filth. In clear water it lives on its own tissues till it is self consumed. It must have the rich carbonaceous compound to draw its sustenance from. Almost the sole supply of such compounds and infusions as the yeast plant affects are those formed by human agency, in beer and wine vats. These are tolerably plenty in Europe, but they are scarce in the western states and territories of America. But every-

where the same processes of brewing and wine making are pursued. The grape, which is fermented without being scalded, furnishes the yeast germs, while the beer-wort, which *is* scalded and which is thus prevented from furnishing the live germs of its own rearing, and which, on account of their scarcity in the air, cannot get them from that source, must be supplied artificially. Schützenberger mentions the great scarcity of yeast germs in the air, and reports that among the various germs and minute organisms, caught by Pasteur in the air, he never obtained *any* of the genuine, alcoholic ferment. We also have Pouchet's testimony to the same effect. Besides, if these organisms "breed true" in an unalterable line, as I infer from Tyndall's language is the theory held by that school of scientists, we have to suppose that the *various species* of alcoholic ferments, of which there are many kinds, are always to be found in the air. They, in many cases, affect a peculiar mode of life and a particular medium for their propagation. One sort is always on hand to start fermentation. Two or three others wait till the first have altered the infusion before they can get in their work. One kind appears to be peculiar to red wine, &c. All these must be present in the air everywhere and all the time if the theory of "true breeding" is true, and all hands agree they are scarce in the air. Prof. Tyndall relates the following experiment conducted by him at the Bel Alp hotel, 7,000 feet above the sea level. He left England with sixty sealed flasks of boiled infusions. Six were broken on the way and became "muddy" with bacteria—which, we infer, were packed in the box with the flasks in England. Four more of the flasks were accidentally broken. The fifty remaining ones are carried to a hay loft, and there the sealed ends of twenty-three of the glass flasks are snipped off. "Each snipping off is, of course, followed by an inrush of air into the flask. We now carry our twenty-seven flasks, our pliers, and a spirit lamp to a ledge overlooking the Aletsch glacier, about 200 feet above the hay loft, from which ledge the mountain falls almost precipitously to the northeast for about a thousand feet. A gentle wind blows towards us from the northeast, that is, across the crests and snow fields of the Oberland mountains. We are therefore bathed by air which must have been for a good while out of practical contact with either animal or vegetable life." These flasks were opened here and the whole fifty then hung up in the kitchen in a temperature between 50° and 90° F. "In three days we find twenty-one out of the twenty-three flasks opened on the hay loft, invaded by organisms—two only of the group remaining free from them. After three weeks' exposure to precisely the same conditions *not one of the 27 flasks opened in free air had given way.*" The shape of the necks of the flasks prevented the germs from the kitchen ascending to the liquid. Prof. Tyndall draws from this the inference

that anybody else would draw; that the germs that were sucked into the 23 flasks were in the dust of the hay loft. Everybody is familiar with that dust. And everybody supposes the hay furnishes the dust. We ought to have been told where the hay was grown. Hay will grow much above 7,000 feet elevation. Suppose it to have grown in the neighborhood of the loft, let us ask how the germs got into the hay. Would the wind, in that supposed pure elevation, have brought germs by the ten millions and deposited them on the hay and nowhere else? If the currents of air up there are practically free from germs, the supposition is ridiculous on its face. I venture to assert that there is not a hay loft in the world in which the same experiment would not have resulted in the same way. The laboratory of the Royal Institution in London appears to be a dusty place. "Of a number of flasks opened there in 1876, 42 per cent. were smitten while 58 per cent. escaped. In 1877 the proportion, in the same laboratory, was 68 per cent. smitten to 32 intact. The greater mortality, so to speak, of the infusions in 1877 was due to the presence of *hay*, which diffused its germinal dust in the laboratory air, causing it to approximate, as regards infective virulence, to the air of the Alpine loft." The inference I draw from these facts is that the germs originate with the hay—that is, a certain sort of germs. Another sort originate with the grape, and another with fruits of different kinds. They may, under favorable circumstances, be carried about in the air just as the fertilizing pollen of plants is carried about in summer. If we should plant a female persimmon tree, miles away from a male, we would not expect the air to furnish those "*unknown things*" necessary to start the young persimmons, but if the two trees are near each other "the air" will furnish the "unknown things" without fail. When the brewer boils his wort he kills all the germs that may have clung to the original barley, and so is obliged to freshly sow it. The wine maker and the kirsch maker are not under this necessity since they do not destroy the germs adhering to their fruits.

Schützenberger, too, observes that other organisms besides the cells of Saccharomyces can excite alcoholic fermentation of sugar; for example, the "elementary cells of larger plants such as are found in fruits, leaves," etc. "The elementary organs of plants in general are endowed, though in a less degree than the cells of yeast, with the property of exciting alcoholic fermentation." M. Fremy has examined the parenchyma of fruits before and after their fermentation and has "found an innumerable quantity of corpuscles which have all the appearance of organic ferments." Schützenberger thinks such fermentation due to a second set of cells, begotten in some way alongside the living fruit cells. Pasteur's opinion, quoted elsewhere, is that the cells of the living fruit themselves are competent to set up alcoholic fermentation, but in addition to

these he found, on the outside of the skins and on the stems of grapes, organic corpuscles which also produce alcoholic fermentation. There is no inconsistency in supposing both these views to be correct. Cells of various kinds are formed in the same organism, whether animal or vegetable. The corpuscles found on the outside of grapes are the true saccharomyces or at least *breed* the saccharomyces in the must of wine. Of those found on the pericarps and petals of fruits, some, at least, also appear to belong to the saccharomyces family.

I think it is in harmony with the foregoing facts to conclude that these fermenting corpuscles are perverted fruit cells developed from the same supply of protoplasm, but outside of the usual conditions of fruit cells, and so appearing in a different form and with somewhat different but essentially equivalent functions; something resembling in a remote degree the formation of a tumor or cancer on the animal body, nourished from the same protoplasm that furnishes sustenance to the normal tissues, in fact itself composed of normal tissue out of place.

If the normal fruit cell under the shelter of skin can produce fermentation, what violence to probability is there in supposing that other cells begotten of the same organism attached to the outside of the fruit, or leaf, or stem, possess the same function. Such cells as these might be regarded as somewhat of the nature of spores. The spores of yeast are formed, as shown elsewhere, by the buds or body cells when placed in contact with the oxygen, and cut off from further access of nutrient protoplasm. Something analogous to this appears to be the origin of the adventitious spores of fruit. At an early period of the development of the fruit, while the young integuments are tender and porous, a cell of fruit or parenchyma finds itself exuded and lodged on the outside of the pellicle exposed to free oxygen, and reduced to limited rations of nutriment, conditions discouraging to the fission or budding which goes on under the skin of the fruit and the bark of the stem, but favorable to the arrest of the cell growth and its crystallization in the shape of a spore. Precisely analogous, I conceive, is the production of the "superficial cellular bodies" that stud the surface of the Begonia leaf, which also possess reproductive powers. That spores produced outside of the fruit case are reproductive of their own kind under conditions affording opportunity for budding, is quite paralleled by the processes of transplanting animal and vegetable tissue generally; as for example in grafting bone cells (marrow) on the back of a dog where they will reproduce and maintain vitality for a season. Their power of fermentation is analogous to that of the cells of the fruit.

The action of the various elements furnished by hay, fruits, etc., which are able to set up fermentation in different kinds of infusions and juices, results in a variety of products, which differ in different in-

fusions. But those of hay, turnip and other vegetables, and of meat, almost always produce *Bacteria* at first, and after the infusion becomes older, other organisms present themselves. It was the presence of innumerable Bacteria in Prof. Tyndall's infusions that made them "muddy." As Bacteria resulted from the dust of the hay-loft in the experiment on the Alps, we must conclude that the dust or spores or germs furnished by the hay were somehow or other responsible for the Bacteria. As remarked above there is not the slightest probability that these Bacteria were carried up there by the air and lodged exclusively in the hay. If they had been they would have been in the air too. I think we must conclude that the spores or germs begotten on the stalks, leaves, or fruit of the hay or grass, developed into the rod-like Bacteria when put into the infusion. This conclusion involves the further theory that these germs do not reproduce themselves or something like them selves, but an organism very different. And this I think is the important lesson taught by these experiments—that those organisms which are elementary in their nature are liable to great variation in their development. The environment which includes the dynamic agencies that operate in their development, has as much or more to do with the direction it takes than any tendency resulting from their origin. If this is true, similar infusions might develop similar organisms from germs of different origin. Bacteria similar in appearance might arise from spores or organic dust from many different sources. But on the other hand, when the infusions are different, different sorts of development may be expected in germs having the same origin. This theory saves us from the necessity of peopling the air with some hundreds of species of vagrant germs nearly all destitute of any visible means of support, yet tenaciously holding to an impossible cast-iron pedigree. If the facts cited are not sufficient to support this theory, we shall have some more in the next chapter.

CHAPTER XXX.

CELLULAR PLANTS, INFUSORIA AND THEIR TRANSMUTATIONS.

"The opinion seems to be pretty common that Vibriones are higher organisms than Bacteria, and that Torulæ are higher than either. Both these views, however, must be received with certain qualifications."* Bastian claims "that Bacteria and Torulæ merely represent two of the most prevalent forms which specks of new born living matter are prone to assume." From the same liquid may be developed, indifferently, Bac-

* This quotation, and most of those which follow, are from Dr. Bastian's "Beginnings of Life."

teria, large and small, Vibriones and Leptothrix filaments, Vibriones and Spirillum, and sometimes Torulæ. The conditions must vary somewhat to develop the different organisms, the variation of tempera-

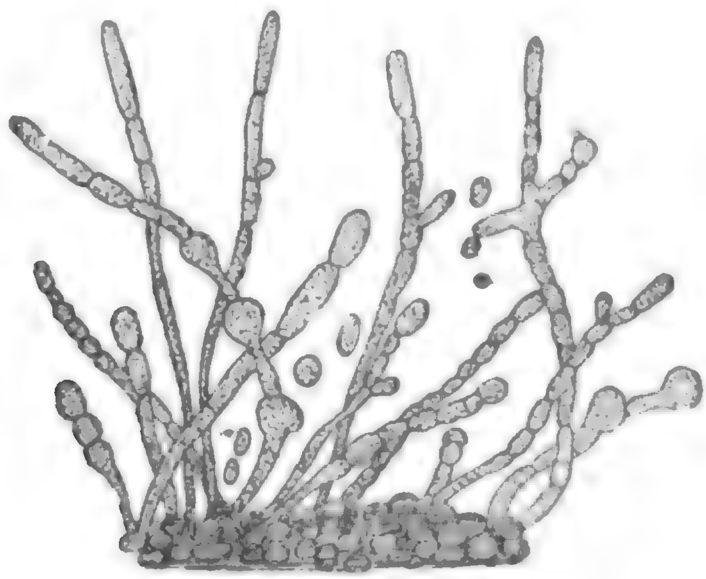


FIG. 105.

FIG. 105.—Development of Torulæ (*Saccharomyces*) found in Cider.
Fig. illustrates the irregular mode of growth and self division of the fungus in this element and the casting off of conidia or spores. (Compare with Figs. 98, 99, &c.) (*Pouchet.*)

ture alone being often all that is required. However, it has been observed "that Torulæ are most apt to present themselves in slightly acid solutions. Again, whilst the most putrescible solutions almost invariably yield Bacteria, the same fluids, after their fermentability has been impaired by the influence of heat, may engender nothing but Torulæ." In most solutions these may be planted and produce their kind. Bastian thinks they both sometimes originate in the same fluid. He and M. Trecul agree that Torulæ in cider will form mycelium and conidia. He claims that "representatives of various kinds of simpler fungi are produced from different Torulæ with the greatest ease. Throughout all the stages of their development there is merely a modified repetition of the simple processes which are ever taking place amongst Bacteria and Torulæ during their more familiar discontinuous growth."[1]

Chiefly on account of the extraordinary and uncertain "sporting" of these low organisms, naturalists are often puzzled in regard to their classification. For example, finding a plant exhibiting a quality supposed to be peculiar to some particular species, it is labeled accordingly. Another observer finding the same plant in another phase of its possible metamorphoses, will assign it to a different classification. Further investigation showing an identical plant, under different aspects, the two distinctive names are supplemented by a third, which is intended to supersede and abolish the others, but which may end by simply adding to the confusion and contributing to the general perplexity.

[1] By "discontinuous" he means broken by reproductive processes—as distinguished from the formation of a crystal which is "continuous," and does not naturally periodically break up to begin again. He calls the first a dynamical and the last a statical condition.

Bastian claims the transitions from fungi (without chlorophyl) to algæ (possessing chlorophyl) to be real and gradual. Out of 200 experiments with solutions in flasks, five furnished green tinted organisms. These he reckoned as being one of the forms of Protococcus (Alga), while from the same infusion were also derived examples of Torulæ. The mixture contained some salts of iron and was exposed to sunlight. "Our experiments tend to show definitely that there is no radical difference between Fungi and Algæ, but that the evolution of the one or the other is regulated in part by the mere presence or absence of certain constituents. Where no *iron* is present, new-born specks of living matter may develop into Bacteria or Torulæ, and gradually unfold into fungus forms, but if iron be present such new-born specks may incorporate this element, develop green protoplasm, and assume the form of Protococcus, with tendencies which may enable it ultimately to unfold into one or the other of the filamentous Algæ."[1]

While the Fungi thus run into the Algæ in one direction, they grade into the Lichens in another. Professor Lindley and Dr. Lindsay, as well as Rev. M. J. Berkeley, are quoted as saying that there is no definite boundary between the two, and there is a large group in which characteristics of both are so blended that their relationships cannot be exclusively established. Furthermore, Algæ and Lichens grade into and develop into each other in the most complicated and bewildering manner. "Green corpuscles (gonidia) thrown off from a single Lichen have been seen by Dr. Hicks to assume the forms and mode of growth characteristic of no less than twenty-three supposed species of Algæ. On the other hand, gonidia thrown off from an Alga or from a Moss are capable of going through any similar number of modes of growth, according as the conditions to which they are subjected undergo variations." As a rule heat and drouth favor development into Lichens, while dampness appears to direct the development of some into Algæ, and others into different forms of Mosses.

Variability among the lowest animal forms is as common as with the vegetables. Difference in the infusions from which they are derived, in quantity, quality or temperature, causes difference in the organisms. This is the testimony of all naturalists in these specialties. "M. Pouchet, moreover, says he has continually seen new forms arise in solutions which never again presented themselves to his observation even in the course of years." He says, "In a maceration of some fragments of human bone which I had brought from the Catacombs of Thebes, and which had remained three months in water, I saw the greater number of the Vorticellæ, of our French fauna, present themselves at once, and in

[1] The figure which iron appears to cut in the distinctions between the Fungus and the Alga, recall its influence in the differentiation of *red* from *white* blood corpuscles.

addition a great number of other forms which, I think, have never been represented. It was quite a new world." Ehrenberg was convinced that twelve species, described by O. F. Müller as belonging to the genus *Vorticella*, were only different modifications of one and the same species. And yet these twelve forms were so different that "Lamark and Bory de Saint Vincent ranged them under several different genera."

All these organisms seem to be destitute of any settled scheme of development. In their modes of reproduction the variations are "almost innumerable," and they have no hereditary bent to dictate any special line of development. There appears to be one impulse behind them all —an impulse *to grow*. But the details of the growth depend exclusively on the environment, including the nature of the infusion, temperature, &c. Remembering that heredity is the habit of ancestors handed down to their descendants, and that the older it is the more firmly it is fixed; these loose habits in these little organisms tend to prove a short line of ancestry. It is true that the elementary nature of these organisms makes them indifferent to the source of their food supply, and more susceptible to its reactive influence upon themselves.

M. Pouchet has adopted an experiment to prove that the ciliated infusoria come from the pellicle which forms on top of the infusion. He takes a wide, flat dish, and in its center he places a tall one of small diameter. Into each he puts an equal quantity of filtered organic solution, and covers both under one large glass bell, thus placing both under the same conditions except as to shape. With a temperature of 68° F. a thick proligerous pellicle is formed in the tall glass and in it plenty of the ciliated infusoria. But when the conditions are reversed, by making the liquid deeper in the shallow vessel than in the tall one, the pellicle becomes thicker and the infusoria abundant in the shallow vessel, while in the tall one the pellicle is thin and the organic product confined to Bacteria. The thickness of the pellicle is necessarily greater over the deeper liquid.

In solutions containing Bacteria under favorable conditions, according to Bastian, who not only relates his own observations, but cites M. Pineau, M. Pouchet and others in confirmation, processes of a synthetic nature take place by which the Bacteria are consolidated into more complex organisms. The scum that forms on the surface of vegetable and other infusions is the seat of these developments. Small tracts of this scum or pellicle become bounded by irregular narrow lines of cleared space. outside of which sometimes there is a border of more densely packed particles which are said to be altered Bacteria. Inside of this boundary there occur fewer of the granulations than beyond the border, but in their place a quantity of jelly-like matter makes its appearance. Next, this enclosure becomes marked off by lines crossing in various directions

forming subdivisions. These subdivisions become rounded or ovoid bodies about $\frac{1}{8000}$ of an inch in diameter, the whole mass aggregating about $\frac{1}{800}$ of an inch in diameter. Each of these subdivisions bounded

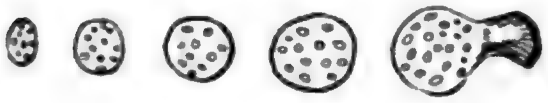


FIG. 106.

FIG. 106.
Showing gradual enlargement of the Corpuscles of an Infusion and conversion of one into an Amœba—Magnified 800 times. (*After Bastian.*)

by a slightly condensed pellicle of its own, contains in its body of jelly from four to eight of the granules of altered Bacteria. It often happens that this development goes no further, but breaks up and is resolved back to motionless Bacteria.

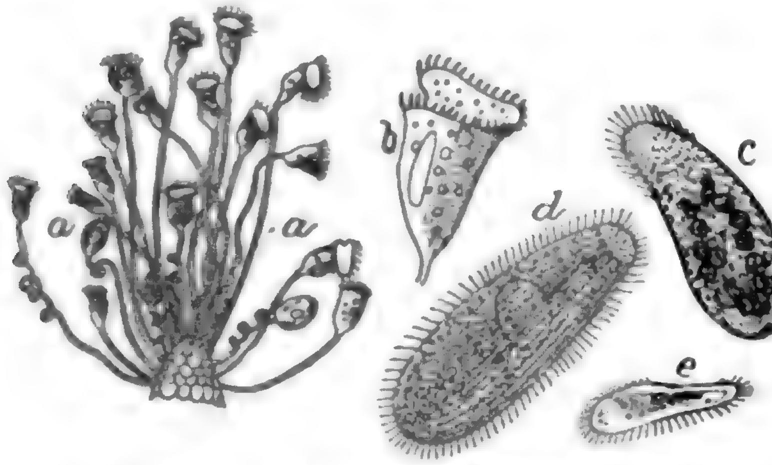


FIG. 107.
a.—Group of *Vorticellæ*.
b.—Single *Vorticella* more highly magnified.
c.—*Kolpoda*.
d.—*Paramecium*.
e.—*Enchelys*.
(*After Bastian.*)

FIG. 107.—Ciliated Infusoria.

But at other times it goes forward and each of the subdivisions or corpuscles becomes an active Amœba and in some cases it may become a flagellated or tailed Monad. These Monads are formed with surprising rapidity, developing at times a tail or whip at each end. After Amœbæ are formed they frequently fuse together, several smaller ones becoming a large one.

The infusorium called the Enchelys by its discoverer Dujardin, is an intermediate organism between the flagellated Monad and the ciliated infusoria Paramecium and Kolpoda. These last two are much alike and do not differ in any essential particular. There can be little doubt that these infusoria will develop from the organic matter contained in a cold infusior of hay. A temperature of only 120° F. seems to destroy the organism of the protoplasm. Like the other simple organisms named above, they take their rise in the "pellicle" or scum on top of the infusion, and their development is somewhat as follows: This pellicle is formed, as before stated, of organic matter in granular form, made up of Bacteria or their aggregated remains. Some of these granules become concentrated into a small, roundish mass, surrounding which is formed a clear, transparent cover which calls to mind the "*zona pellucida*" of the higher animals. Inside of this, which soon becomes a well defined membrane, the granular matter, after being first dispersed throughout the fluid matter contained in the cell, is formed into an em-

bryo Paramecium, or it may become segmented into two parts, each of which becomes an embryo, or these two may subdivide each into two, thus forming four segments, each of which becomes a young Paramecium inside the cell. After a short time these embryos become active and tumble over each other, and finally rupture the membrane enclosing them and swim out into open liquid. The stages through which they pass are essentially those of the Monads and Amœbæ. Their shape when grown is "obovate, slightly compressed, ends obtuse, the anterior attenuated and slightly bent like a hook." Their diameter is about $\frac{1}{450}$ of an inch. They are ciliated and contain one or more vacuoles like Monad and Amœba.

The reproduction of the infusorial animalcules is various. In some instances it has been observed to take place by fission, the parent splitting into two, a slow process said to cover many hours, or even days. In other cases it is by means of ova or germs, which are produced by the conjugation, contact or coupling of two individuals (in certain species). This is likewise a slow process, the conjugation sometimes lasting a week, and the ova appearing two or three days thereafter. This would appear to be a truly sexual conjugation, although there are no sexual organs or parts. We may suppose one of these animal specks to be positive to the other negative, and coupled together by this "polar force" be compelled to mingle their constituents in the production of a third body.

Another mode of reproduction, which may be a supplement to or modification of the last, is one in which the germ develops inside of and apparently at the expense of the parent. Sometimes there are two or three of these germs, and their development causes the death of the parent, and their birth its rupture and dissolution. (See also the same process in the development of the white blood corpuscles.)

As to the manner of the development of these little organisms I propose the following theory: By the process of macerating the hay in cool water, the protoplasm of the hay is soaked out without injury to its vitality; by which I mean its molecular constitution, by virtue of which, while the hay was green and the protoplasm a fluid, it coursed its way up and down the stalks, like blood pulsating through the veins of an animal. When the hay was dried, the constituents of the protoplasm were retained in its tissues entire, minus merely the greater part of its water. In the process of maceration, this water is restored and the protoplasm, freed, floats to the top of the liquid. It is in a new element, but its molecular polarity must be regarded as capable of controlling its aggregation of particles into masses, more or less definite in size and shape. While these masses take, in the vascular tissues of the hay when alive, such shape and action as their environment there imposes upon them, it

could not be predicted what sort of an effect a change of environment might have on them; nor could any reason be antecedently assigned

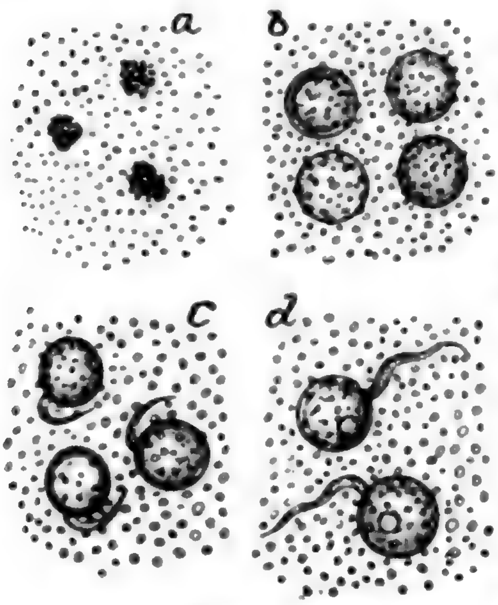


FIG. 108. Development of Monad (*Monas lens*) from a pellicle formed on an infusion of hay in six days.
a, b, c.—Quiescent stages of development.
d.—Flagellum vibratile and Monad active. (Magnified 1800 diameters.)
The size of the Monads—*d*—is 1-2500 of an inch. (*After Pouchet.*)

FIG 108.

why these masses, so active in the cells of the plant, should not be active in another medium, giving equal or greater freedom to their movements. I do not regard this as a case of "spontaneous generation," or generation *de novo*, but simply a transfer of living from one environment to another, and a new development appropriate to and in consequence of the new conditions. The same theory applies to most of the life development from infusions of organic elements. New habits of life are imposed upon old organic materials. The theory accounts for the development of many of the numerous forms of low life that follow upon the death of any highly developed organism. The air may carry occasional germs of live or dead, green or dry ferments, that may at times originate development in infusions, but it is incredible that the air is everywhere burdened with the germs of thousands of species and varieties of organic life.

FIG. 109. *Dust* from the *Air*. Collected by Pasteur, and found to contain Organic matter, Germs, &c. (Greatly magnified.)
a.—Collected June, 1860.
b.— " January, 1861.

On this subject M. Pasteur says: "In conclusion, we see that ordinary air contains only here and there, and with no continuity, the necessary condition for the initiation of the so-called spontaneous generation. Here there are germs, whilst in immediately adjoining portions of the atmosphere there are none. Further on there are other kinds of germs, and there are few or many of them, according to the nature of the locality."

M. Pouchet also examined the air by the most approved methods, and found large quantities of debris, both mineral and organic. He found granules of starch abundantly scattered about, plenty of epidermic tissue and particles of chlorophyl. Of spores of fungoid bodies

and the single celled algæ, protococcus, &c., a limited number were intercepted, but of the *infusorial animalcules*, or their spores, ova remains, or products, he *never* found *one*, in the course of observations reaching into the hundreds. The larger infusoria are $\frac{1}{250}$ of an inch in diameter, and their smallest spores $\frac{1}{1650}$ of an inch. The fungus spores run from $\frac{1}{9000}$ to $\frac{1}{3300}$ of an inch. Starch particles from the air run from $\frac{1}{750}$ of an inch down. It follows, therefore, that the infusorial products were big enough to be seen when the others were. Of the whole of the dust products filtered from the air, only from one-half to one-third (of one) per cent. are of organic origin.

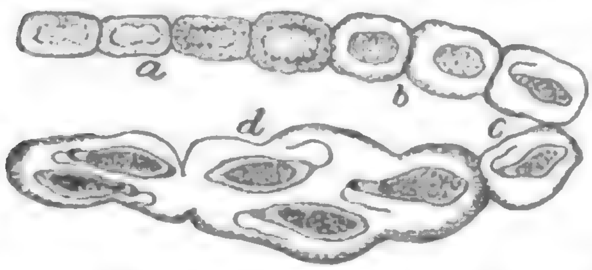


FIG. 110. Development of *Euglena* from cells of a *Confervoid Alga.* (*Dr. Gros.*)
a.—Unaltered cells of the Alga.
b.—Aggregation of the cell contents, first stage toward forming the individual.
c.—Individuals assuming form of Euglena.
d.—Several cells thrown together by the obliteration of the partitions.

Within the walls of a cell of a confervoid Alga after being sometime in water, Dr. Gros has seen the protoplasm gradually assume the form and characteristics of the Euglena, which is a green plastic vesicle that generally moves about with the help of a long anterior flagellum or tail in front. *Astasia* is another variety hardly distinguishable from Euglena. They have chlorophyl in their interior, and like vegetable products do not take visible food, animal in form but physiologically apparently vegetable. Bastian also claims to have seen Euglenæ formed in the small cells composing the submerged leaves of the Potamogeton (Pond weed). Euglenæ there formed were as mobile as Amœbæ, moving about within the cell walls. They were bright green, the whole of the chlorophyl and protoplasm having been absorbed in the creation of a Euglena. Observations of Prof. A. M. Edwards are to the same effect.

Bastian states on the authority of M. Nicolet, that under proper conditions the protoplasm of the confervoid Alga, Chara, after being placed in pure water, gives birth to a multitude of living organisms which, after a time, undergo further modification into various forms of infusoria, passing in 15 or 20 days through various stages into Monads, Amœbæ, Keronæ, Vorticellæ, Actinophrys and Rotifers. M. Nicolet says: "A vessel prepared on the 29th of April and containing a single cell of Chara (a single internode) yielded on the 15th of May following, in addition to an incalculable number of (smaller) infusoria, 137 specimens of the common Rotifer, two-thirds of which had been produced by reproduction."

It was the opinion of Louis Agassiz that the ciliated infusoria as a rule are to be regarded as elemental or larval forms of other animals, "most of them" (he says) far from being perfect animals, are only

germs in an early stage of development. The family of the Vorticella exhibits so close a relation with Bryozoa, and especially with the genus

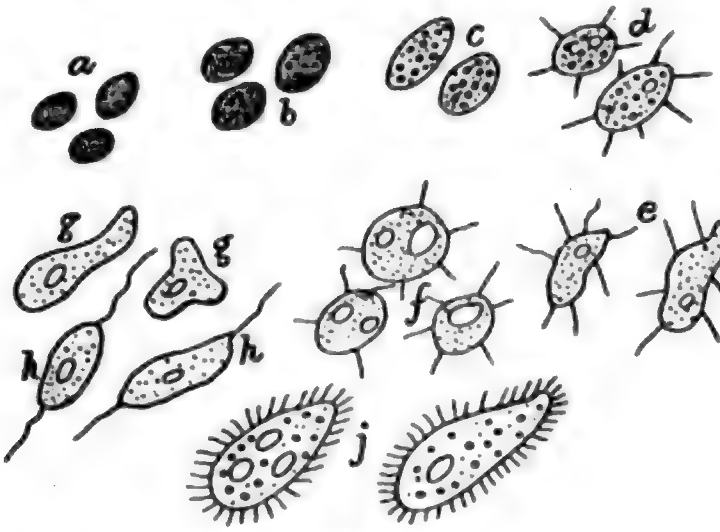


FIG. 111.

Transformation of Chlorophyl Corpuscles (× 600)—(*Bastian*).
a.—Pale unaltered Chlorophyl Corpuscles of Nitella (confervoid alga).
b—Others alongside of first, larger, of darker green and slightly granular.
c.—Others more discolored, a few green granules still remaining.
d.—Similar Corpuscles with motionless rays and vacuole.
e.—Similar ones formed into sluggish Actinophrys.
f.—First stage in forming some of the Actinophrys into Amœbæ, *g*, and others into Monads, *h*.
j.—Organisms like Enchelys, probably developed from the Monads or Amœbæ.
These transmutations took place in an internode of Nitella, 2½ inches long, after being corked up 5 weeks with water in a test tube.

Pedicellina, that I have no doubt that wherever Bryozoa should be placed, Vorticella should follow and be ranked in the same division with them. The last group of Infusoria, Bursaria, Paramecium and the like, are as I have satisfied myself by direct investigation, germs of fresh water worms, some of which I have seen hatched from eggs of Planaria laid under my eyes." * No better proof need be required of the origin of the Molluscoid Bryozoan with its tentacular arms, from the Infusorium with its vibratile cilia. We have here an organism arising in two apparently different ways; one by evolution of the organism from an inferior form, and the other by *birth* or reproduction from a superior form. For example, an Infusorium arises by development from an infusion, and another just like it comes from the egg of a Worm. This history repeats itself in the development of the higher animals including Man as we have seen; the larval or embryo form of every one being at different stages like the *mature* forms of inferior animals. In the case of the infusorium and worm, the imitation is more exact than in that of higher organisms, that is all. Bastian is of the opinion that the *gregarinæ* which are formed in the bodies of lower animals, may be derived from the white blood corpuscles. While the white corpuscles are themselves developed from globules of lymph or chyle. Bacteria are formed in many blind cavities of the animal body, the liver, brain, etc. M. Trecul discovered within the cells and lactiferous vessels of certain

* Annals of Nat. Hist., 1850, vol. vi, p. 156.

plants, great numbers of bacteria. Observing their development to be accompanied by a production or deposition of starchy matter, he named them Amylobacteria, or starch bacteria. There exists, he says, in the bark of the common Elder and in that of plants belonging to the Nightshade and Orpine families, a number of cells which are filled with little tetahedrons having slightly unequal sides. It is these little tetahedrons which he has seen converted by development into the starch bearing organisms. The tetahedron becomes elongated at one of its angles, and produces a cylindrical outgrowth, the body of the tetahedron itself, either retaining its shape or becoming rounded, remains as a bulb. This growth all takes place within cell walls, it sometimes happening, however, that the walls of two or more cells become ruptured and the cells thrown together, forming a larger cavity (Bastian).

The instability of the lowest forms of animal and vegetal life is much greater than in the highest. The organism that is old is supposed to be more conservative and fixed. This is undoubtedly true in the main. The most recently acquired function or anatomical adjustment is more easily lost or perverted than an older one.

So Bastian argues that the extremely various forms taken by the most minute and simple of both animal and vegetable organisms is proof that they are recent in origin from the mineral kingdom and not necessarily descended from the first organisms of their types that ever came into existence. He says, "That some Moulds, Amœbæ, and other lowest organisms, should have lived in unbroken continuity through pre-Silurian epochs amidst all the changes of the Carboniferous, Triassic, Oolitic, Cretaceous, and more recent geologic ages, with that mutability as an essential characteristic which they are now seen to display, and yet that they should have undergone little or no alteration, seems to me almost too incredible to be seriously entertained." This point is well taken. It is extremely unlikely that Moulds, Amœbæ, or any other *fungoid* or *parasitic* forms now extant, depend for their origin on an ancient ancestry like themselves. In fact, as has been shown elsewhere, many of these parasitic forms are degenerate and backsliding descendants of more or less ancient stock. They themselves may be, and probably are, comparatively recent—in their present condition. This condition is the result of new habits induced long after the stock first originated. The organisms having these new habits of parasitism and getting their living from other organisms, are in no necessity to be constant and stable in any particular except that of eating and reproducing. As their eating is merely the absorption of food already prepared for assimilation, and as the food is prepared through a great variety of sources, from any of which the parasitic organism could get it almost equally well, it follows that the organism may adopt vari-

ous details of vagrancy without jeopardy of the main chance. Such change of habits might make a difference in various ways, including the general morphology of such parts as the locomotive, absorptive and reproductive. These are held in every mode of life subservient to the question of sustenance.

On the other hand, however, it is not necessary to admit that there are not now to be found on earth conditions for living, almost precisely like what might have been found in every age since the Silurian. We have genera of Molluscoids and Crustaceans that have come down to us with very little alteration from the earliest geological times. The Lingula, a most conservative little Mollusk, who remains during life anchored by his stem to the bottom of the sea, has representatives buried in the strata of every age from the Silurian up. While great changes have taken place on earth, we are bound to perceive that there have always been tracts of sea water neither too hot nor too cold and furnished with enough food to support the Lingula without requiring any great change in the functions of his life. These spots have sometimes been in one place and sometimes in another, and the wide distribution of the animal has been effectual in always placing some of his tribe in an environment so congenial to his ancient hereditary habits as to require little or no adaptive change in him. If one of his haunts was raised by the slow oscillations of the earth's crust, and turned into dry land, its very slowness gave him time to transfer his plantations into the deep water.

The small crustacean Ostracoids have likewise survived without much change, and so have several others, and for the like reason, that there has been a uniform submarine climate extending throughout the geologic ages, slowly shifting from one tract, or series of tracts, to another, and transferring its animal and vegetable life with it.

While this view shows how it is possible that a conservative type might be perpetuated indefinitely with little change, it also shows that substantially the same conditions which may be supposed to have been necessary to originate organic forms in the first place, have never ceased to exist, and are to be found on earth to-day. There appears no reason why the process of the development of organic life from the mineral kingdom may not be going on to-day.

On many accounts the present must be fully as favorable for the development of animal life from vegetable as any preceding age. Vegetables exist in great abundance, and in greater variety and higher development than ever before. I have shown elsewhere how vegetable protoplasm might become separated from its natural resources of food supply in its native vegetable, and by receiving its supply from foreign sources become an animal or a parasitic fungus. The opportunities for

such transformations are probably greater now than ever before. Bastian's claim that he has been able constantly to evolve animal or fungus vital organisms from mixtures containing vegetable infusions but destitute of germs, is not at all unreasonable. But, on the other hand, in a state of nature, new and unsettled forms of life, whether vegetable or animal, have a much smaller chance for survival in the struggle for life now than they would have had in the very early times, because there are so many more higher organisms that depend on these lower ones for their food supply, and, therefore, gobble them up as soon as formed.

CHAPTER XXXI.

ZYMOTIC AND GERM DISEASES.

Modern discovery has established the fact that the animal body affords very good conditions for the subsistence of hordes of invisible parasitic organisms. No animal body, big or little, is exempt from contributions levied by some of these organisms. The fact was suspected by our ancestors before the use of the microscope had enabled them to learn its true nature. They reasoned from what they could see with the unaided eye. They could see insects. I believe it was Dean Swift who formulated the idea thus :

> " Big fleas have little fleas, and these have less to bite 'em.
> These lesser, have still smaller fleas, so on ad infinitum."

The reality was much worse than they suspected. The terrible plagues that devastated Europe during the middle ages, were due to parasites far worse than fleas. The blood, lymph, and other rich juices of the animal body, are as good food for the single celled bacteria, vibrios, micrococci and such like, as they are for the cells of the legitimate tissues of the body. When these adventitions germs enter the body, they proceed to live on this food, and a struggle for life ensues between the old settlers and the new comers. In some cases, however, there is enough for all, and it often happens that we are the unsuspecting residences of tribes of bacteria on whose account we are apparently none the worse. These presumably live on what the normal cells of our tissues can spare ; in some cases, perhaps, on what they excrete.

There are others which, by dint of numbers and insatiable greed, consume so much of the food supply as to impoverish and starve the normal tissue cells ; and others still which so destroy and pervert the secretions and nutritive fluids, that they are no longer fit for the use of the legitimate tissues.

There is a certain degree of definiteness and constancy in the organi-

zation of the different tribes of these bacteria, which renders it possible to cultivate and study them separately. This has been, and is being done, to the incalculable advantage of the human race, by many such men as Pasteur and Koch—Nature's Nobility. Like causes always produce like effects, and the cultivation of microbes or the propagation of a disease *without change* in their character, depends upon the maintenance of *identical conditions*. Professor Tyndall in speaking of the work of Pasteur in the cultivation of unmixed races of these "germs" says: "By teaching us how to cultivate each ferment in its purity, in other words, by teaching us how to rear the individual organism apart from all others, Pasteur has enabled us to avoid all these errors. And where this isolation of a particular organism has been duly effected, it grows and multiplies indefinitely, but no change of it into another organism is ever observed. In Pasteur's researches the Bacterium remained a Bacterium, the Vibrio a Vibrio, the Penicillium a Penicillium and the Torula a Torula. Sow any of these in a state of purity in an appropriate liquid; you get *it*, and it alone in the subsequent crop. In like manner sow small-pox in the human body, your crop is small-pox. Sow there scarletina, and your crop is scarletina. Sow typhoid virus, your crop is typhoid; cholera, your crop is cholera." This statement is true; the first part of it literally so. But we must not get from it an impression that there is absolute and invariable constancy in the reproduction of these organisms, because it certainly cannot be maintained that they are any *more* constant or breed "truer" than other and higher organisms, visible and tangible.

Prof. Tyndall provides that they be sown in an *appropriate liquid*; and this is the saving clause, for if it be *not* appropriate we can depend upon it the organism will be more or less perverted. It is certainly a fact that these small organisms are far more at the mercy of their environment and subject to far greater changes from it in proportion to their size, than are larger and more complex organisms. Organic chemistry informs us, that the alteration of an atom in a body consisting of a single molecule, may make a totally different thing of it. The action of its environment upon every organism, big or little, produces in it atomic alterations. Every movement of an organism involves atomic or molecular displacement and changes the organism by that much, and it will remain changed unless its virility and individualism enables it to recover.

Papillon remarks that the yeast cells which produce alcohol in different fruits are slightly different in form from one another, and from those of grape, must or beer-wort, these variations being due to the medium acted upon as the different fungi, will grow in any one of the media.

If putrid matter containing vibrios be injected under the skin of a dog, they will grow in the blood, reproducing with great rapidity until

the animal is poisoned, unless very healthy and vigorous. They multiply like yeast in barley-wort. The blood from such dog, if injected into another animal, will be found more poisonous than the first injection; and each subsequent injection, and further remove from the first inoculation is more virulent than the previous one. From this it is evident the vibrios have undergone a change. Those from the last dog are different from those from the first. They have become acclimated and newly adapted to a new environment. In such cases as these the change of environment from that which is "appropriate" is not great, and the change in the organism is correspondingly small; but we must be prepared to expect that great changes in the organism will follow important changes in the environment.

I have shown elsewhere how easily organisms of a high order are affected while in their earliest embryonic condition, that is, their unicellular condition, or within a few removes from it. In fish hatching, when the appropriate conditions are followed as closely as possible, the normal egg may produce such an abnormal fish as one possessed of two tails, or two heads, or two backbones. Those organisms which unicellular to begin with never get much beyond that, are fully as liable, in an *inappropriate* environment, to get a crooked start, and to reproduce something different from themselves. Nor is this the assertion of a new or exceptional doctrine. It is simply the fundamental doctrine of evolution—that the organism is subject to its environment, changing when it changes. I object to the term *spontaneous*—especially *spontaneous generation*. There is no such thing. When an organism "sports" and reproduces something different from itself, it is in consequence of being under the influence of an environment different from that which produced *it*. And conversely if the environment *is* different the organism is bound to sport. The change may be great or little, perceptible or imperceptible, but there is a change. But it follows further, that if all the conditions are precisely the same, the organism will "breed true." And it was the ability to preserve uniform conditions that enabled Pasteur, and many others after him, to cultivate and breed different races of Bacteria.

Of *Contagious Diseases* there appear to be two kinds, and they are comparable in every respect to the two kinds of fermentation. The first answering to the fermentation caused by active vital organisms, is likewise caused by vital organisms which, starting either from the germ or from the mature organism, grow and reproduce in the blood and tissues of the victim as parasites. The second sort acts like the soluble ferments, and may be communicated by the living cell or by its remains or products.

A consideration of some of these diseases will show that they come under the laws governing organized bodies, and are subject to the same struggle for existence, and the same development and modification by their variations of environment and habit. I have, in chapter 25, given the history of several disease breeding parasites—such as Trichinæ—which are easy to be discovered. But those mentioned in this chapter were not suspected to exist until comparatively lately, though of their effects sad experience has long been had.

*Splenic Fever** is a virulent and fatal disease which attacks not only the human race but also horses, cattle and sheep. Tyndall says that in Novogorod, a district of Russia, from the year 1867 to 1870, fifty-six thousand horses, cows and sheep, and five hundred and twenty-eight men and women were destroyed by this disease. And large numbers have perished in other parts of Europe. This disease is caused by a parasitic organism, the nature and habits of which were finally made known by the investigations of Dr. Koch. Beginning as a spore this organism, in an appropriate fluid, in a few hours develops into a rod-like body which subsequently grows by adding to its length till that is several hundred times greater than its diameter. Inside of this filament there soon appear a series of dots, which develop into ovoid bodies occupying the entire inside of the filament, like peas in a pod. These are the spores. Later, the filament dissolves, leaving the spores in a long row ready to repeat the operation. These spores may be dried and kept for years without losing any of their malignant virtue. In order to give the disease of *Splenic Fever* they must be taken into the blood, where they produce the morbid alteration and degradation which soon disqualifies it for the nutrition of the tissues, and ends by the death of the victim. Mice whose blood was inoculated with these spores soon died. But a mouse might eat a diseased tissue and so take the virus into the stomach with impunity. The name of this parasite is *Bacillus Anthracis*. It is singular that it will not propagate in the blood of dogs, partridges or sparrows; but flourishes in the blood of mice, guinea pigs and rabbits. The immunity of the birds appears to be due to the high temperature of their blood, which is about 109° F. against 98° as the temperature in man.

The disease among the silk worms of France, known as *Pebrine*, is caused by a vibrio called Psorospermia, which pervades all the tissues of the body, and is always fatal. The discovery of the nature and cause of this disease is due to Pasteur.

Psora—vulgarly called *itch*, *scratch*, *Scotch fiddle*, &c., is well known to be caused by a small insect, which can be communicated from one to another by contact. It is more annoying than dangerous.

Muscardine—A disease existing among silk worms in France 50 years ago, was caused by a fungus which grew in the blood of the living animal, and which made its appearance on the outside of the body after death. The disease could be conveyed to other worms and to other species of Lepidoptera by inoculation, and it could also be *produced* in otherwise healthy and untainted Silkworms, or other insects, by feeding them for a time in close, damp bottles or boxes. Once developed, by whatever means, it became contagious, and very fatal.

Septicæmia and *Pyæmia*—Blood poisoning which sometimes supervenes upon wounds, are accompanied and supposed to be caused by bacilli or micrococci. Bacteria have been found during life in the blood of septicæmic patients, and they are usually observed after death. Inoculation of healthy animals by septicæmic blood from an animal of the same or a nearly relative species, will convey the same disease.

Septicæmia induced in mice by the experiments of Koch, were accompanied by *rod-like* bacteria, while in that produced in rabbits the organisms were *oval* shaped. These diseases could not be transferred by inoculation from either to the other. It would appear from these facts that the organisms in blood poisoning are from the air and fall into the exposed wounds where they set up fermentation accompanied by their own growth and reproduction like torula in a saccharose solution. Blood poisoning is fatal in a majority of cases.

There are two kinds of small-pox; viz., *Variola* and *Varioloid*. The latter is merely a milder type of the former, and is the form the disease takes when it is communicated to a person who has had small-pox or cow-pox, or when small-pox is communicated to a fresh patient by inoculation instead of the ordinary miasmatic contagion. When the blood is inoculated with the small-pox virus the disease develops in a shorter time, by several days, than otherwise. In the disease following this inoculation the eruption is slight, the pocks rarely exceed 100, and many do not suppurate. The mortality in this disease, when it was cultivated artificially, was from one-half of one to three per cent. "Transferring the virus from persons successively inoculated, the disease becomes progressively more and more modified until at length, as a rule, to which there are exceptions, the eruption consists only of the one pustule formed at the point of inoculation, with a few pustules developed around this mother pustule."[1] As a rule, a person who

*I suppose this is the same disease called "blood" by Dr. Bastian.

[1] Flint's Medicine, P. 1041.

has had varioloid never has the small-pox thereafter, but if a person not protected (as by vaccination) be exposed to the contagion of varioloid, however mild it be, he is in the same danger of regular small-pox as he would be from exposure to small-pox itself. So that the disease is different only as the condition of the victims is different. As is well known both sorts of small-pox are extremely contagious and portable by means of clothing or otherwise. The epidermic excreta of this disease, as well as those thrown out of the system by the breath, are carried into the air and set up the disease in others by being swallowed or taken into the mouth, and then penetrating to the blood through an epthelium or mucous membrane. It is remarkable that the disease taken in this the natural way should be so much more severe and fatal than when taken by inoculation. Taken in the natural way the mortality is from 10 to 33 per cent. Small-pox prevents its own return, as a general rule. It is accompanied by the round bacteria, or micrococci, which are found in blood vessels of the skin, and sometimes in the blood vessels of the liver, spleen, lymphatic glands and kidneys.

Vaccinia, or cow-pox, is a disease of cattle, which bears some resemblance to the human small-pox. The lymph of cow-pox contains micrococci, which are similar to, if not identical with, those in the lymph from the small-pox vesicles. Cow-pox is transferable to the horse, in which animal it is called *grease*. It appears in the horse as an inflammation affecting the skin of the heels. Inoculation with matter from the *grease* produces in man the disease called *grease-pox*—(variola equinæ) which, in the prevention of small-pox, has precisely the same effect as cow-pox. There is also an epizootic, or contagious disease, called *murr*, which affects sheep—the French call it *clavelee*—which is analagous to, if not identical with, cow-pox. Cow-pox is contagious among cattle, spreading rapidly at times through several herds, at other times spreading slowly. It is not dangerous; fatal cases being extremely rare. Men have caught the disease from cows while milking them. I should suppose the milk of diseased cows would communicate it, but have no authority for it. This disease is so nearly like small-pox that it prevents small-pox in the same way in which that disease is a bar against its own return. However, its influence wears out and inoculation must be repeated after a term of years—variously stated from three to twenty. Cows may be inoculated with human small-pox and be affected by the symptoms of cow-pox only. But vaccination of a human subject by virus from *such* cow-pox *may* communicate the disease of genuine small-pox. Vaccination is almost as effectual against a recurrence of small-pox as small-pox itself. And when it does return after either, it is in the form of the comparatively mild varioloid. It is not settled what constitutes the contagium of these diseases. "The experiments of Chauveau have rendered it probable that the contagium is a molecular substance, and is not dissolved in the lymph." (Flint.) I think the facts warrant the conclusion that all these diseases have had a common origin, and have received slight modifications from long habit in slightly differing environments; and that they are due to either an organic or soluble ferment, or both together.

Varicella or *chicken-pox.*—This is another eruptive disease which prevails chiefly among children, but sometimes is experienced by adults. It is contagious among children, but seldom so with adults. It is characterized by the formation of small vesicles on the skin filled with a liquid, which finally dry up without leaving pits. The symptoms so much resemble those of varioloid as to lead often to erroneous diagnosis. But it is not known to develop into variola or varioloid, and may prevail in the absence of either. It is no protection against either of the other diseases. Where the miasm is originally generated, or what causes it, is not known; but it is contagious and sometimes epidemic. It is comparatively harmless and cures of itself if let alone.

Scarletina or Scarlet fever is a contagious eruptive disease more common in children three or four years old than in adults. As a rule it is only experienced once. It is accompanied by high fever, scarlet redness, and eruptions of the skin, violent inflammation of the jaws and pharynx, often extending along the eustachian tube into the drum of the ear, and is followed by desquamation or a peeling off of the epidermis. The contagium of this disease is contained in the exhalations of the breath, and those from the skin, thrown into the air, and are often carried in the clothes of attendants for long distances, and infected garments, furniture, &c., may be able to communicate the disease long after they receive the contagium. The disease often follows surgical operations. No vital organism has been observed in connection with scarletina.

Another eruptive, contagious disease is the well known ***Measles*** or *Rubeola*. It is often of an epidemic nature. It is portable, being carried from one place to another by persons who have been near it. It is in general characterized by fever, watery eyes, serous discharges from the mucous membrane of the nose cavities and ad-

jacent sinuses, inflammation of the pharynx, eruptions over the surface of the body of a dull, red color, and a peeling or desquamation over a greater or less extent of the body. It is very rarely that the disease makes a second attack on the same victim. This disease by itself is not usually dangerous, but it is often complicated with other diseases and becomes serious, the fatalities at times reaching five per cent. or more.

Roseola or rose-rash is an eruptive disease which resembles scarlet fever in some of its symptoms so as to be sometimes mistaken for it. It is in reality, however, a faint imitation of scarlet fever and is comparatively harmless. It is not followed by desquamation and may come a second time. Yet, by some it is claimed to be contagious. It is often epidemic.

A disease called *German Measles*, or by the Germans, Rötheln, very closely resembles a mild form of measles, and is said to be mistaken for it. This disease is epidemic, and may attack the same person more than once. Both these diseases are supposed to depend on a "special cause" or contagium.

Another disease of the eruptive sort has occurred in the Southern States and other warm parts of both America and the eastern hemisphere. It is called *Dengue.** Its symptoms are extremely violent, but seldom fatal. In 1828 it is said that 10,000 people had this disease in the city of Charleston, S. C., at one time. There is generally fever and an eruption, sometimes hemorrhage from the nose, mouth or bowels, sometimes discharges of serous matter from the mucous membrane of the nose. Some claim it to be contagious and that it prevents its own return. It runs its regular course in about eight days. No medical treatment has any other than a palliative effect.

Diphtheria † is a disease that has been known from the most ancient times. The name, which means *skinny* or *membranous*, and has been given to it during this century, alludes to one of the peculiarly dangerous and characteristic symptoms of the disease; namely, the formation in various parts of a false membrane. This membrane is formed by exudation of certain fibrinous matters through the mucous membranes, which matters remain as coatings upon the mucous membranes and form thereon this false layer. The fibrinous material forming this false membrane Flint says, "consists in part of fibrillated fibrin and in part of epithelial cells, pus and connective tissue cells, which have undergone the peculiar metamorphosis called coagulation-necrosis. Bacteria, both rod shaped and in the form of micrococci, or according to Klebs, of Monads, are often found as colonies in the false membranes." It is not proven that these organisms have any special agency in the production of the disease or the membrane. They are similar in appearance to others found in decomposing substances. The false membrane is the same in diphtheria that it is in membranous croup ("Laryngitis with fibrous exudations") including the presence of the bacteria, &c. In some cases the false membrane rests loosely on the mucous membrane below, and may be stripped off more or less easily; in other cases it is connected by infiltration of fibrous matter with the mucous membrane below which also contains fibrinous matter, so that the two are with diffculty separated until after a period of three or four days, when the separation becomes easy. The former or loose false membrane is called the croupous, while the latter is called the diphtheritic. Both sorts of the false membranes are, however, apt to occur both in croup and in diphtheria.

In most cases of diphtheria the parts primarily affected and from which the fibrinous exudations take place and upon which the false membrane is formed, are the pharynx and parts communicating with it, as the tonsils, the soft palate, and the pillars of the velum of the palate. But it often goes further, and the larynx, the trachea, and bronchi, may become involved, or the disease may spread up the eustachian tubes into the ear drums, or into the nasal cavities, or upon the mucous membrane of the gums, cheeks and base of the tongue. But not only this, "the lips, the arms, the vulva, the vagina, and the prepuce are sometimes effected." Flint 1075. The greatest danger from this disease, as from croup, is the stopping up of the air passages by the growth of the false membrane, although if the patient escapes this there are numerous other chances of the disease making away with him. The disease does not often occur sporadically. It is epidemic and it is contagious to the extent of being easily portable. There are many examples of this disease starting under circumstances which seem to prove it to have originated afresh; that is, it was not communicated from any previous human patient. It is believed to have originated from the exhalations of the partly dried beds of ponds, from offensive cess-pools, from the use of foul water, &c. It is true such places might possibly be nurseries, in which germs are caught and bred, and at favorable moments sent forth

* Pronounced Deng-gā. In the British West Indies it was called "Dandy" fever.

† Also called Cynanche, malignant sore-throat, &c.

upon the air. But it is extremely probable that in such places many kinds of microbes, bacteria, &c., are developed, or rather perverted from the disintegrating tissues of organized materials.

Typhoid Fever. The first effect of this disease is an *altered* state of the blood, accompanied by a reduction of its fibrin and increase of its *white* globules, which means failure to turn the white globules into red ones. This deterioration of the blood soon communicates derangement and degeneration to many of the working parts —especially to the Peyers glands or "patches" and follicles of Lieberkühn, situated in the lower part of the small intestine. These become inflamed and swollen, then congested and perhaps ulcerated and sloughed off. The ulceration may extend to the outside coat of the intestine and eat holes through it, the effect of which is speedily fatal. The ulcerations may heal and the patient recover. The intestinal ulcerations are always accompanied by more or less enlargement of the *mesenteric glands*, especially those in most immediate connection with the intestinal glands. This enlargement is due to an abnormal increase of cells like the normal ones of the glands.

The *spleen* is generally enlarged to two or three times its normal size. There are degenerations of the substance of various parts, as the liver, the kidneys, the glands of the stomach, and some of the muscles. There are changes in the lungs, including congestion and inflammation of the mucous membrane of the bronchial tubes, and ulcerations of the larynx are not uncommon. There is generally an eruption over the body of isolated pimples ⅛ of an inch long, of ovoid shape. Several observers have found in the ulcerated organs in the intestine, colonies of the ovoid micrococci, while others have found the rod-shaped bacilli in the laryngeal ulcerations. Emanations from the bodies or breaths of typhoid patients thrown into the air do not, as a rule, communicate this disease. If they contain a contagium it is not at first active. Flint suggests that "they may become infecting agents after certain modifications or developments have taken place under conditions which pertain to decomposing human excrement." The infection of the disease, at all events, in some way gets into drinking water and is communicated by that means in a vast number of cases. The disease frequently breaks out and affects all in a neighborhood who use the water of a particular well, which, when examined, is found to be liable to contamination from some cess-pool, privy or drain. Flint relates that a gentleman left his house in town shut up during the summer which he and his family spent in the country. On the return of the family in September all the members of the family between the ages of 7 and 22, seven in number, became sick, one child with a fever and vomiting, not typhoid, and the other six with typhoid fever. One died. "On examination of the premises the waste pipe in the cellar was found to be defective, and at times a bad odor from it had been perceived." "The disease was not prevailing in the neighborhood." This case appears to have arisen from the accumulation of a miasm in the confined atmosphere of the cellar. And its infectiousness depended upon its accumulation and density. Doubtless if the cellar had been ventilated the infection would have been so dissipated and attenuated as to be harmless. It seems clearly not to have come from a typhoid patient directly or remotely. Many cases might be cited in which the origin of the disease is free from any suspicion of the agency of any previous typhoid disease, but none in which the agency of corrupt and fermenting matters cannot be traced.

Mountain Fever is a disease arising from the use of the water of mountain springs and rivulets, which has been contaminated by the excretions of sheep, cattle, &c. It is the same as typhoid, and occurs in the stock ranges of our western mountain districts.

Typhoid fever is so called from its resemblance to *Typhus fever*. Typhus fever has been called also Ship fever, from its being landed in America from emigrant ships. It closely resembles typhoid fever in most of its symptoms, the most notable difference being its exemption from the intestinal lesions and ulcerations which characterize typhoid fever. It is more contagious than typhoid. Patients, especially when many are together, as in a hospital, are apt to give their disease to their nurses and attendants, their emanations being sufficient without modification or development to convey the infection. A single patient in a large, well ventilated room does not often give the disease to others, but many together in the wards of a hospital, if ill ventilated and small, pack the air with the infectious miasm. The disease can also be carried in the clothes, &c., when they have been well saturated with the miasm. "The disease sometimes appears to be developed as a consequence of overcrowding and deficient ventilation; in other words, the concentrated emanations from the bodies of healthy persons, apparently suffice for the generation of typhus germs. Outbreaks in jails, hospitals, workhouses, ships, and unventilated tenement houses crammed with occupants are thus

accounted for in some instances irrespective of contagion." (Flint.) It appears from the foregoing that *typhoid* and *typhus* fevers are due to one or more *zymases* or soluble ferments which are engendered in dead tissues and excretions of men and other animals. The baccilli micrococci, &c., probably arise from the perversion of tissue cells in the body, and are a consequence of the disease, rather than its cause.

Mumps or *Parotiditis* is another of the contagious and infectious diseases, which often, if not generally, appears as an epidemic. It never occurs more than once to the same person. The principal feature of the disease is usually the inflammation and swelling of the parotid salivary glands, just below the ear. Sometimes the swelling also attacks the other salivary glands, the submaxillary and sublingual. In the case of males over the age of puberty, there is one chance in four of the disease being transferred to one of the testes, and then there are four chances in ten that this gland may become atrophied. In females, too, the disease may be transferred to a mammary gland and an ovary. The transfer of this disease to another set of glands is curious and not satisfactorily accounted for. It appears to be due to a ferment which somehow alters certain secretions.

Whooping Cough, a familiar, but none the less remarkable disease, is another of the contagious or infectious diseases, which is never known to originate except by a contagium which very few escape, which very few ever have a second time, but which very seldom destroys life. The disease consists of these essential elements: 1, inflammation of the lining membrane of the bronchial tubes or bronchitis: 2, fever, and 3, an affection of the nervous system which brings on the spasm in coughing and whooping. These three constitute the disease. The disease may last from six weeks to several months, and begins from one to two weeks after exposure to the infection. This infection consists of the emanations of breath and body carried about in the air which probably have the effect of a *zymase* in the alteration of some secretion of the body.

Relapsing Fever. This disease is apt to prevail with typhus fever, but is independent of it. Neither disease ever communicates the other, though each is in its own way infectious. In this disease, generally, the spleen is enlarged and softened, due to congestion and hyperplasia (excess of fibrin) of its lymphoid contents (Flint). The liver is enlarged, its tissues becoming degenerated, and the kidneys are swollen. The heart is liable to become degenerated, and granular fatty cells, and white blood corpuscles are apt to accumulate in the blood. The blood also contains a spiral shaped bacterium, called the *Spirillum* of *Obermeier* from the discoverer, a physician of Berlin. The parasites occur in no other fluid besides the blood, and in no disease except relapsing fever. They are lively and active during the active stages of the fever, but disappear during the relapses or intermissions. The diameter of the spirillum is about that of the finest fibrils of fibrin, and its length from one and a half to six times the diameter of a red blood corpuscle. Efforts to cultivate the organism artificially have failed. It resembles a spiral organism found by Cohn in the mucous of the mouth, another discovered by Ehrenberg in water, another found in fluid from noma or aquatic cancer, and still another from a cyst in one of the nasal cavities (the antrum highmorianum). The attack from this disease is sudden and the fever runs high, usually continuing from five to seven days. Then there is a sudden cessation or "relapse" lasting from three to five days generally, then another paroxysm of fever and another relapse of eight or nine days, a third paroxysm of three days, the whole lasting perhaps twenty-five days. The symptoms are not invariable, but differ in different epidemics of the disease. Some think the disease is caused by the spirillum, and the periods of relapse are its sporing seasons. If that were true, ought not the relapses to be all of the same length to correspond with the time required for the metamorphoses of the organism? The mortality in this disease, considering its fierceness, is low, running from two to eleven per cent. of those affected. It is communicated from the sick to the well. The contagium requires to be concentrated like that of the typhus, in order to insure its communication to others. A single patient in a well ventilated room does not usually give the disease, as a number of patients together in small wards are apt to do. The disease may disappear as it did in London for 14 years, then suddenly come on as an epidemic. It goes with famine, destitution, crowding and dirt. It is some times called "famine fever" and "hunger pest."

Texas Cattle Fever. This is contracted by the Texas cattle along the strip bordering on the Gulf of Mexico and within 300 miles of the gulf. It results from crowding together in a malarious region. The form of the disease is not very violent, as it affects the Texas cattle themselves, but when these are driven north, and come into contact with the northern cattle, they give to the latter a form of the disease that is very fatal. It is communicated only through the dung and urine, which saturating the grass

of pasturage, is taken into the stomach. It is always characterized by enlargement of the spleen. It does not appear to be communicated from one northern animal to another. Frost at once destroys liability to communicate the disease. (Tellor, Diseases of Animals.)

Rinderpest is an infectious disease which, originating on the plains of Asiatic Russia, travels west into Europe. It attacks chiefly cattle, but also sometimes sheep, goats and deer. It is the most fatal of all cattle diseases. The contagium is thrown off into the air by the suffering animal, and it may be carried by a healthy animal from an infected district to a healthy one and start the disease in the latter place. It is characterized by high temperature and by pimples on the mucous membrane of nose, mouth, vagina, &c. Death usually occurs on the 7th day after the manifestation of the presence of the disease. (Tellor.)

Epizootic, also called Pink-eye, is a horse disease, contracted from a contagium spreading through the air. It is characterized by discharges from the nostrils accompanied by cough. It is often fatal. In the epidemic which spread through the country in 1872, it is said that the deaths of horses reached 10,000 a month in the Atlantic states.

Pleuro Pneumonia, is a contagious lung fever which affects cattle. Sometimes the contagium reaches one lung only; at other times both. In the latter case the disease is fatal.

Consumption is now reckoned as one of the germ diseases and several physicians, among whom is the celebrated Dr. Koch, claim the distinction of having discovered the organism that does the mischief. The disease may be conveyed from one to another, there is little doubt, by means of the debris of the broken down, diseased tissues.

Another highly contagious, but rarely fatal febrile disease, is an *Epizootic* which attacks cattle and sheep, and is sometimes communicated to pigs and man. It is characterized by an eruption of small blisters in the mouth, between the clefts of the hoof and along its upper margin at the coronet. It is dependent on a specific cause, claimed by some to be a vegetable organism, by others an animal. It generally terminates favorably after a run of one or two weeks.

Glanders or *Equinia*: A disease very contagious to horses, asses and mules. When they are put into a stable in which the disease has been, they are likely to take it even when the stable has been thoroughly cleaned, aired and whitewashed. It also originates with horses when their general vitality is reduced by overwork, foul air, and filthy stables. It is also liable to be generated by putting horses into new stables whose walls are not dry, and it is a frequent sequel of diabetes, influenza, the epizootic disease, and other exhausting complaints. This disease is communicated to man by inoculation in the blood—as when a person having cuts or sores allows the discharged matter from ulcerations of glanders to come into contact with them and so get into the blood. Thus taken, a fatal termination is rarely or never escaped. The disease is incurable and as soon as a horse is known to have it he is summarily killed.

Yellow Fever. This disease is acutely infectious. But it is thought by most observers to be not contagious. Every year at New Orleans there are some cases of it—sporadic—which are accounted for by the supposition that some germs are always lurking concealed in clothing packed away in out of the way places, which are liable to turn up any time and produce a greater or less number of cases. At times when some peculiar state of air or water, or both, co-operate with an unusual accumulation of sewage, or other decaying and fermenting organic matters, the disease may become epidemic, and be disseminated to considerable distances. It can be carried in clothing and otherwise, and along river and railroad thoroughfares. Frost kills the germs and stops the disease. It prevails in the cities along the coast in the hot parts of the United States, but not often in rural situations. During epidemics of the disease in cities, multitudes always run away to the country and generally escape the disease.

In this disease there are liable to be morbid changes in the liver, the stomach, the intestine and the kidneys. The liver takes on a condition of fatty degeneration, indicated by the presence, both in the cells and the interstitial tissue, of drops of fat which also impart to the organ, in many cases, an abnormal yellowish color. The mucous membrane of the stomach is usually swollen, softened and congested, and this condition extends some distance down the small intestine. The kidneys are generally enlarged and undergo degeneration of the parenchyma. The spleen appears not to be disturbed, and no changes have been observed in the blood not seen in other fevers. Dr. Flint says no

organism, which could be supposed to be concerned with this disease, has been found in the blood or any of the tissues. The period of "incubation," or the time elapsing from the time of exposure to the disease to that in which the disease is developed in a patient, is frequently but two days, but generally somewhat more, sometimes the period is as much as 15 days. The attack is generally abrupt, and after a preliminary chill, fever sets in and the temperature soon reaches from 102° to 110° F. This stage of the disease lasts from a few hours to three days. After the cessation of the fever the disease may last from 12 hours to three or four days. The mortality ranges from ten to seventy-five per cent., differing greatly in different epidemics. The general average is estimated at 43 per cent. An epidemic generally terminates within 60 or 70 days, the general average being stated at 58⅓. The contagium of the disease is certainly to be considered as being an infectious miasm. Hence persons may be near patients affected by the disease without taking it, while others secluded completely may still get the disease. The dejecta are supposed to furnish germs to the air more abundantly than the gaseous emanations from the body, if indeed the latter are not entirely harmless.

Epidemic Cholera. This disease is said to be indigenous and endemic in India. There are two opinions in regard to its relationship to sporadic cholera, or cholera morbus, as it is called in this country, and to cholerine or diarrhea. In some cases, during a cholera epidemic, persons are affected by the diarrhea, and their symptoms end with that. It is adjudged often that such persons have had the cholera, because cholera begins with such symptoms and usually passes on to the more violent and serious symptoms, unless suppressed by proper treatment. It is therefore held by some authorities that these diarrheas always represent a simple form of endemic cholera which, under proper conditions, might expand into epidemics.

Mr. McNamara, of Calcutta, is quoted by Dr. Bastian as saying that "Cholerine is simply a modified form of Asiatic Cholera, and is capable of engendering this more deadly form of the disease in other people by means of the dejecta." The Asiatic Cholera after becoming epidemic is apt to extend into other countries. It reached the United States in 1832, again in 1834, was here again in 1849, and was not got rid of till 1852. It came again in 1866 and remained during that year and the next; and lastly came in 1873. Notwithstanding its migratory character it is said not to be contagious after the manner of typhus or small-pox, but, like yellow fever, to supply the germs for dissemination in air from its dejecta—both the matter vomited and purged. This matter while fresh is not capable of producing the disease. But as soon as voided, fermentation proceeds from the action of germs which were developed in the fluids before their evacuation from the alimentary canal, the conditions of this fermentation involving several days time and hot weather. It is favored by being mingled with quantities of the fermentable and putrifiable filth of sewers, cess-pools and stagnant water. This theory is fortified by the fact that the fresh excretions have failed to produce the disease even when taken into the stomach or by inoculation, or any kind of exposure to them or to the sick. This theory is held by many doctors. "It is supposed that these germs are produced within the alimentary canal, not only in the cases of fully developed or well marked cholera but in cases of so-called cholerine, the latter as well as the former affection being caused thereby." (Flint.) If the virus of the excretions from cholera patients is allowed to set up fermentation in any sort of reservoirs, or accumulations of stagnant filth, these become breeders of the miasm, which, taken up by the air, may be carried many miles and produce the disease in localities free from any suspicion of contagium. This miasm is likewise transportable in clothing, &c., and frequently travels along the great public thoroughfares of river or rail. An obvious way to get clear of the disease is to clear away all the possible nesting and breeding places, and to burn up the excretions from the patients. The cremation of the victims would do no hurt. Many low vegetable organisms have been found in the dejecta of cholera patients, as sarcinæ and bacteria, both ovoid and rod-shaped, but none of them have been shown to be characteristic of this disease or have anything to do with its cause. The same forms of organisms may occur in ordinary diarrhea. From this it seems as reasonable to suppose these organisms may be begotten from broken down tissue cells in the body, as in an organic infusion out of it.

Erysipelas, or St. Anthony's fire, consists of "a superficial inflammation of the skin, with general fever, tension and swelling of the part; pain and heat more or less acrid;" accompanied at times with small vesicles upon the inflamed part, which dry up and scale off. (Dunglison.) It is sometimes a merely local affection confined to one spot, often the head. At other times it is accompanied by a continued fever, to which the name *Erysipelatous fever* is given. This is sometimes sporadic; at other

times it becomes epidemic. This last, the epidemic disease, is a dangerous one. It is called also "black tongue," from the occasional appearance of the tongue. It appears in isolated places at the same time, its miasm or infection doubtless being conveyed in the air. It is not directly contagious, but rather infectious-miasmatic.

Puerperal Fever arises from inflammation of the peritoneum, which may attack a woman after the birth of a child. The disease is infectious and has been known to go through a whole hospital. It has often been observed that during epidemics of Erysipelatous fever, Puerperal fever becomes much more prevalent; and this has led to the opinion that the erysipelatous infection is able to set up the latter disease in subjects who have been reduced in health and strength in certain organs. In other words, the same "germ" or "ferment," if that is it, produces a different growth in different soils.

Epidemic Bronchitis or *Influenza.* This disease is remarkably epidemical, being very extensively and rapidly diffused, and affecting a great number of people at the same time. It affects the mucous membrane of the nasal passages, and of the frontal sinus and other cavities connecting with them; also the eustachian tube, the conjunctiva,* and the tear ducts. These affections are accompanied by a fever. It is an infectious disease communicated by means of the air which carries the miasm. An attack of this disease lasts from three to six days and is rarely or never fatal unless accompanied by other diseases or the weakness of infancy or old age. It has been observed that other diseases are more severe during the prevalence of influenza.

Another epidemic disease is *Ophthalmia.* There are several varieties, some of which are contagious. One of severity and danger is called Egyptian Ophthalmia. It consists of inflammation seated chiefly in the coats of the eyeball, and extends in some degree to the eyelids. Another variety is a contagious granular conjunctivitis or inflammation of the conjunctiva. This is also epidemic and contagious, and very common in some of the middle portions of the U. S. It may be "caught" by a person wiping his eyes on a napkin or towel used by another who has sore eyes.

Hydrophobia or *Rabies.* This disease arises in certain seasons and in certain localities in dogs, foxes, wolves and cats "spontaneously." From them it is communicated to other animals including man, by blood inoculation. The virus of the disease is contained exclusively in the fluids of the mouth; viz., the saliva and mucous from the throat and bronchi. There is no proof that other fluids of the body are competent to communicate the disease. The inoculation takes place when by a bite the rabid animal impregnates with its venomous saliva the *nerve tissues* of the victim. The disease does not make its appearance till 30 or 40 days after the inoculation. A great many who are bitten are not inoculated, and many who are inoculated do not take the disease. Some say, that of those bitten not over one in twenty contracts the disease. In many cases the saliva is wiped off the teeth by the clothing, &c. After the development of the disease death usually follows within five days. The treatment is usually to cut out the mutilated part as quickly as possible and cauterize it. Animals who do not naturally bite, do not communicate it, although they may have it. The seat of the disease is said by Dr. Duboue, of Pau, to be in the *brain* and *spinal marrow.* The virus is not in the blood, but is carried by the nerve and nervous fibers. This accounts for the delirum which attends the disease and for its long period of incubation, which would probably be much shorter if the inoculation were through the blood.

Endemic Diseases. There is a class of diseases which depend on local causes. In a certain place, or class of places, a person may be liable to take a certain kind of disease which he would not be liable to in another locality, perhaps not far away. These are called *endemics.* The causes are miasmatic emanations from the soil or water, or from decaying organic matters in the locality producing the disease. Many of such diseases after being started by local miasm, or contamination of some kind, are thereafter infectious, as for example milk sickness. But in the same way is not almost every disease infectious? We reject the flesh of all animals that have died a natural death, regardless of the cause, and the butcher who kills a diseased animal and offers to sell it is regarded as a criminal.

Among the endemic diseases, one of the most common and well known is *Fever* and *Ague,* or chill-fever, or intermittent fever; a disease which has been greatly lessened in this country by the improvements incidental to the settlement and cultivation of the country; such as the drainage of marshes and swamps, the clearing away of thickets or underbrush, and turning over the rich soil so as to allow the penetration of air

* Conjunctiva is the mucous membrane of the eyelids and outside of the eyeball; it connects the ball and the lids.

and sunlight. The exhalations and emanations arising from the new soil which must consist chiefly of organic matters in various stages of decomposition, and, what is more to the point, of recomposition, all go under the general title of *malaria* or *miasm.* There must be, however, different varieties of malaria. At any rate there are different forms of fevers which depend on malaria for their exciting cause. Some of these may be due to modification of and development from intermittent fever. What is called *pernicious* or *malignant intermittent* fever prevails at times in malarial districts and is apparently an intensified form of the intermittent. In plain intermittent there is frequently an enlargement of the spleen, and sometimes in prolonged cases this becomes permanent and so prominent that it can be felt from the outside of the body. It is called *ague cake.* In the pernicious type of the fever the spleen is liable to become enlarged, and occasionally a black pigment is found in the blood. Another form or derivative of the intermittent, is the *Remittent* fever. In *intermittent* fever there are cessations or intermissions in which there is no fever. In the *remittent* the fever does not stop, but only slackens up and becomes less intense.

These two are said to be mutually convertible into each other. Simple remittent fever is not usually dangerous. It is characterized by pigment granules in the blood and in the spleen, liver, and marrow of the bones. In the mild form of the disease there is but little of this pigment, but it is present in quantities in the violent forms. In some cases the coloring matter is found in the brain, especially in the gray matter. The pigment of *Melanæmia,* as this blood coloring is called, it is agreed by physicians, is formed out of the coloring matter of the red blood-corpuscles (Flint). Typhoid fever may be present with remittent at the same time in the same patient, and it preserves its characteristic symptoms of intestinal ulcerations, &c. When the disease is complicated thus, it is called typho- malarial fever.

Milk sickness. This disease has been prevalent in many districts in the states between the Alleghany mountains and the Mississippi river, and I suppose is still occasionally experienced. It originates with cattle, horses and sheep which graze in some particular localities; especially from grazing in them at night. But what they eat that gives it to them no one has ever found out. While one particular hillside, bottom or meadow may originate the disease, another locality close by may be quite free from it. As a general rule, plowing, cultivating and raising crops on an infected spot has banished the noxious element, whatever it is. Cows giving milk usually escape but the milk is so poisoned that their calves, and any other animals using the milk, including man, are liable to the disease. Likewise a slut giving milk may escape, while her pups will contract the disease. Carnivorous animals, and man, acquire the disease by eating the milk, butter, cheese or flesh of diseased animals, which they may do quite unwittingly. The hides of animals which die from the disease are specially poisonous, and when nibbled by rats and mice are as fatal to them as ratsbane. The infectiousness of the flesh is not destroyed by boiling, nor does the water in which it is boiled become affected—showing that it is not a soluble poison.

The mortality among men in this disease is about forty per cent. "After death the spleen is found dark and congested, the brain softened and the blood uncoagulated." "The disease appears to be a modified form of cerebro spinal meningitis, the only difference being the less strongly marked cerebral manifestations and the more diffluent blood." (Neil and Smith, Practice of Medicine.)

Dysentery, as a sporadic disease, is tolerably well known to almost everyone. It consists of inflammation of the mucous membrane of the large intestine, particularly the colon and rectum, with fever, and mucous or bloody discharges from the bowels. The discharges often contain fragments of mucous membrane, rotten and gangrenous; and also large numbers of bacteria. The disease occurs chiefly in the summer and fall, and oftener in warm climates than cold. Its cause is thought to be miasmatic. Sporadic cases are generally manageable, but the disease may become epidemic and it is then more malignant. The intestinal ulcerations may cause perforation of the intestinal walls. It is apt to become epidemic in armies, and other crowded bodies of men, in hot weather. As an epidemic it is infectious, and the characteristic inflammations are caused by an agent from without. Emanations from the dejections no doubt assist in the propagation and continuance of the disease when started. Large numbers of bacteria, and sometimes infusoria and fungus spores, are found in the excrementitious matters. But these organisms are found in so many states of disease, and even health, that it is not safe to predicate anything upon them. They may have something to do with the propagation of the disease, or they may be only an effect of it. Some doctors have supposed that the intestinal excreta contain a virus, by means of which the disease may

be communicated. And it is rendered pretty certain that it is conveyed by means of clothing, &c. (Flint.)

Dysentery usually begins as a plain *diarrhea*. Vigorous remedies of the proper sort, if applied in time may arrest the disease in that stage, so that the subsequent stages are omitted. It has even been arrested in the stage of dysentery which follows.

Goitre or *Bronchocele* is a disease which is rare in any other than a mountainous region. It is most frequent at the base of high mountains in every part of the world. It consists of an enlargement of the *thyroid gland*, which sometimes becomes very large. After a long time it becomes hardened into a cartilaginous condition, in which state it is incurable.

Leprosy or *Lepra* exists in three species. In one of these the skin is covered with scales, in another it is covered with crusts or scabs, in the third with tubercles. These forms of Lepra are said to be endemic in Egypt, in Java, and certain parts of Norway and Sweden. *Elephantiasis*, a disease similar to Lepra, generally attacks the feet and legs, which swell to a large size. There are several varieties of this disease, some of which are hereditary and contagious and incurable. In one variety the disease affects the lymphatic glands and the areolar tissue under the skin. The disease exists in Barbadoes Island, and others of the Antilles, in Arabia, in Cayenne (S. A.), in India and in Java. There are a few lepers in Louisiana and Colonies in the Sandwich Islands and Mexico. In each locality the disease appears to have taken on habits due to peculiarities of the place.

It is evident that there is an evolution in many diseases, as in other organic existences. Take any of the contagious or infectious diseases enumerated above, except splenic fever, pebrine and some others, and we see a development in the exciting cause. The "exciting cause" of a disease lurking about some swamp, or other locality, having the proper breeding conditions, develops sporadic or scattered cases; a greater intensity of the exciting cause produces a greater number of cases, and then it is an endemic; another addition to the intensity of the exciting cause and the disease becomes epidemic and infectious. In passing through these experiences the exciting cause evidently undergoes modification. There can be little doubt that in many cases this exciting cause is at the beginning some sort of an organic cell capable of expansion and multiplication by the budding process, or fission, when under the stimulus of heat and in the presence of an abundance of nutritive organic matters. As before observed, it is well known that many varieties of parasites have taken the liberty to make their homes in various quarters of the human and other mammal bodies. Some of these have been mentioned. Some of them give us no trouble, and we are often not aware of their presence. Others annoy us but not dangerously; while still others are more or less injurious, and some fatal. Of these parasites some are of a considerable degree of organization and of large size, often inhabiting the larger cavities of the body. Others are microscopical in size, extremely elementary in organization, and live upon the blood or some special secretion. To this last class belong some that are quite harmless, and of whose existence we are generally unconscious. But a great many also belong to this class whose presence is a cause of disease more or less serious. Of the harmless kind may be mentioned the *Leptothrix buccalis*, which consists of a thread-like process or mycelium, and is almost always present in the mouth. The cells and spores of the microscopical Algoid plant, called *Palmella*, are sometimes found in the secretions and mucous expectorations of healthy persons, in places not malarial. (Flint.)

The nature of the cells which constitute the miasm from which endemic diseases originate, is largely a matter of analogical inference from their effects. They may be surviving cells of tissues of plants that have become dissolved and disintegrated by water soaking. Or they may be diverted cell growths, in which cells, composed of the normal protoplasm of some tissue, are formed outside of the walls of the tissue in some such manner as we have found fruit cells formed outside of the skins of fruits. Or, finally, they may constitute new modes of organic growth originating from a recombination of protoplasm disengaged from disintegrating plant or animal tissues.

In any event when taken into the system these cells find in the fluids of the body suitable conditions for their multiplication, and their mischievous action on the human body will produce a certain type of disease. But they themselves receive modifications in the process of their development, because the conditions under which they are placed in the animal body are different from the conditions under which they are supposed to have been originally produced. Now if the cell, as changed by a generation of existence in the human body, is taken into another body, it will be found to live in a somewhat different manner and produce a modified type of the disease. And so on during several generations or transmigrations of cell life.

In many cases the virility of the race of disease-producing cells seems to reach a culmination and then decline, becoming less and less vigorous, the epidemic declining both in the number of people affected and in the violence of the disease, till it finally dies out as if of old age. And that, I take it, is precisely the case. Otherwise, why should it ever stop? It must be that the repeated modifications of the disease cells brought about by the constant or repeated reactions against them of the united cell organization of the body finally alters them into a condition in which they can be either assimilated or ejected, or in which they are at any rate harmless.

The investigators who have given the subject of fermentation the most patient attention, and who ought to know, regard the soluble ferments as *inorganic*, that is, while they are products of organisms, they are only manufactured articles, which by virtue of their composition and make up, produce certain effects upon infusions and animal fluids, but which do not reproduce their kind by a gemmation or fission. If the theory in diseases, of fermentation, or of "germs," "bacilli," "vibries," "microbes," or anything of the sort, or all of them is to be adopted, it seems consistent to include an insoluble *zymase* as the product and companion of the self-reproductive organism, as it is of the saccharomyces, &c. Where the two go together, it is easy to see their possible competence to achieve the mischiefs of contagion, &c. But there is also this probability; that the zymase may become separated from the organism which produces it, and carried through the air to work alterations in such suitable fluids as it may meet with. For example, suppose the organic juices of a rich swamp to be the home of organisms, like the Torula or other microscopic plants which give rise to their corresponding zymases. After awhile the swamp dries up partly, and great numbers of the organisms become dessicated and perhaps disintegrated. But the disintegration of an organized plant does not destroy its zymase; it only liberates it and allows it to be carried off by the air. I think many *endemic zymotic* diseases may be accounted for in this way. But if when the swamp dries up, the organism itself is blown about, we get a regular germ disease. A disease arising from a zymase alone might be infectious because the zymase being a catalytic agent is not supposed to lose much, at any rate not for a long time; so after having "altered" the blood of one victim it may be transferred to another in the dejecta and come to the second attack with but slightly impaired powers.

The circumstance that these diseases become reduced and finally die out, recall the action of the soluble ferments. As shown elsewhere, if consecutive generations of these ferment cells be cultivated in the *same sort* of a medium, after a time they become less virile and active. In order to renew their vitality and activity it is necessary to transplant them to another medium. The true theory of this phenomenon is without doubt that the reaction of the medium in which the ferment cell is raised, modifies the cell itself and finally neutralizes its activity.

The kind of cell, therefore, which lies at the basis of the malarial diseases, and some others, is one which sets up an alteration in the blood or some other fluid. In consequence of such alteration, the proper functions of such fluid are ill performed or not performed at all. The different sorts of disease ferments, as they might be called, affect different parts, as the secretions of the salivary glands in mumps, the secretions of the intestinal glands in typhoid fever, the secretions of the pituitary or schneiderian membrane in influenza, the blood in several diseases causing fibrinous exudations in one part or another.

The elective quality on the part of these disease ferments is analogous to that exhibited by vegetable and mineral poisons; thus "alcohol and opium exert their effects on the brain, arsenic on the intestinal tract, strychnia on the spinal cord, mercury on the mouth, phosphorus on the liver, aconite on the heart, &c." (Dr. Flint.) Different lengths of time are required for the "incubation" of different sorts of these ferments, some only a few hours, and some a number of days, or even weeks, just as different kinds of yeast are a long or short time in leavening a batch of bread. But I suppose also some of the tissue cells and fluids of the body are more easily disorganized than others, a fact which may contribute to this difference.

During the progress of an epidemic of a certain class, the fermentation is evidently communicated to deposits and collections of organic matter, such as ponds of stagnant water, cess-pools, sewers, &c. Thus the sewers of Memphis had the yellow fever during the two years in which that disease played such havoc with that city. In the following season after they had taken measures to keep the miasm of the sewers out of the houses, and had thoroughly cleaned and disinfected the sewers, although the disease was still prevalent along the Mississippi river, they escaped. From this it would appear that the miasm of the disease pervading the air was deficient either in the number of the disease cells or germs, or in their virility to produce an epidemic, till these cells were reinforced by a fresh crop raised in the sewers.

A remarkable example of epidemic cholera attacking a mass of putrifying organic matter, and being communicated from it, is given by Dr. Carpenter in his Physiology. It occurred at the Almshouse, situated two miles from Baltimore, Md., in the summer of 1849. The inmates of the establishment numbered 632, of whom 99 died in about a month. The causes of the presence of the disease were discovered to be a mass of putrefying matter from cess-pools, drains, and pig-sties, which had been allowed to find its own way to a drain back of the establishment, but which covered considerable ground on its way thither and had become concealed by a growth of weeds. This stuff was ditched off to the drain, followed by drenching with water; the saturated soil was covered with lime and over that a thick layer of earth. The day after this was done the number of cases of cholera in the almshouse dropped from eleven to three and within two weeks the disease entirely disappeared. The cases were nearly all in the parts of the buildings on the north side, exposed toward this infected ground, and to the wind which generally blew from that direction. Certain rooms on that side which were shielded by nothing more than a barrier of trees escaped.

CHAPTER XXXII.

DIFFERENTIATION.

The term differentiation implies that a homogeneous or mixed whole is divided into two parts which are unlike, as skim-milk and cream. Air is composed of two unlike gases, oxygen and nitrogen, and its properties are the sum of the properties of these components. The analysis of air by which the parts are separated from each other, each part taking off from the compound the properties peculiar to itself, is analogous to organic differentiation. The low forms of animal life—as the Monera, &c.,[1] consist of protoplasm, each particle of which is indistinguishable from any other particle, and possesses the same properties that any other particle has. It is composed chiefly of carbon, hydrogen, nitrogen and oxygen, and it has what may be called its positive or native properties, which are the resultant outcome of the properties of the several elements which are included in its make up. Besides these it has other susceptibilities which might be called its negative properties. These consist of its pliability and susceptibility to the influences and movements of the surrounding environment, as touch and pressure, and such forms of energy as heat, light and electricity. It is to the impulses of these outside energies upon the animal that all his movements are traceable. His movements are, in fact, only the movements of his environment, diverted, reflected, refracted and reinforced by the chemical forces or positive properties residing in himself. For example, a certain degree of heat is necessary to enable any sort of movement on the part of the animal. If the temperature should sink to within 5° or 6°, centigrade, his power of motion would cease. What may be called the muscular movements of the Moneron are performed by the extension and contraction of one part or another of its mass of proto-

[1] As a matter of strict fact the Monera are already more or less differentiated, but as the differentiations have not gone too far it serves as an illustration.

plasm. Contraction of muscle is the result in general of electrical stimulus, and the necessary amount of electrical energy for the purpose of this contraction may be generated by any one of several other forms of energy, such as light, heat, or touch, or pressure by another body, when such forms of energy are applied to the muscle. Further on we shall see how these various forms of energy are interconvertible into each other, but here it is enough to state that the structure of muscular protoplasm, if not of all protoplasm, is of sufficient sensibility to be affected by the electrical energy generated by even a touch, a ray of light, a beam of heat, or a sudden compression of the air or vibration of the water in which it may happen to be. Even vegetable protoplasm is contractile under electrical stimulus.

Now, in the Moneron the differentiation of parts has not gone far enough to exempt any of its protoplasm from this contractility; any part stimulated will act as a muscle, contracting at one point and thereby necessarily pushing out at another. In one sense, therefore, the whole animal is a muscle. A particle of foreign matter suitable for its food, coming adventitiously into contact with it, excites a different sort of reaction. In the process of muscular contraction certain molecules composing the organism have become disrupted by the tearing out of the carbon atoms. The elements about the voids thus left remain with unsaturated affinities, or, in other words, are hungry. They are therefore all impelled alike towards such accidental atoms of carbon as are available for new combinations, and so the food is surrounded, and the animal, after first becoming all mouth, is next, for the time being, all stomach. The atoms suitable for assimilation being extracted from the food particle, the several elements of the animal shrink from the unassimilable remains of the repast, and so, by their common movement, an act of excretion is accomplished. Respiration is a process by which oxygen from the air is brought into contact with the atoms of carbon in the tissues of the animal. Without it no sort of animal movement can take place. In the Moneron each molecule of its protoplasm must come into direct contact with the air and so allow the oxidation of its carbon. Probably intermolecular movements of the protoplasm alternately bring the interior molecules to the surface. So the lungs of the animal may be said to be coextensive with its body. It is all lungs. According to the statement above, that external stimuli arrested by the tissues of the animal are converted into quasi electrical vibrations, it follows that these vibrations must traverse the mass passing from one molecule to another; from those more exposed to the direct influence of the stimuli, to those less exposed. For in even a Moneron we are bound to suppose top, bottom and sides, even though the parts are continually exchanging positions. Each molecule is therefore to be considered a vehicle for the

conveyance of the electrical stimulus to its neighbor molecules, and the whole together as forming a sort of nervous system. Furthermore, it must be conceded that an electrical stimulus propagated throughout the mass of elements composing the animal would tend to establish a correlation and correspondence of action between the different elements, so that the movement of one would of necessity influence the rest. Such correlation and redistribution of stimuli is the function of ganglions, and is in reality the elementary form of purpose or will. A multitude of ganglions constitute a brain. The Moneron, as a whole, therefore, must be considered not as *having* but as *being* a nervous system, and the correlation of stimuli by which definite and co-operative movement is assigned to his various parts, must be regarded as his mental action.

The reproduction of the animal is accomplished by his simple division into two pieces—fission. When the animal reaches its adult stage it suffers a constriction across the middle, which, gradually deepening, finally becomes a bisection, and the one adult is thus reduced to two infants, each to begin life over again and repeat the experience of the parent.

We find, therefore, that in this simple animal are produced the phenomena of eating, digesting, assimilating, growing, and reproducing its kind, also respiration, contractility and the movement of parts, susceptibility to the influence of touch and radiant energy, and finally nervous co-ordination.

Formidable as this list of powers appears, we should find it difficult to conceive how any animal not a parasite could exist with fewer, and in truth there is none that does. On the other hand, what animal possesses more? Expanded, developed, differentiated in a thousand ways and a hundred thousand fold they may be and are, yet, after all the expansions and differentiations, their powers are still comprehended under the general terms that describe the powers of this humble animal. The proofs and illustrations of this statement will appear as we advance. In the mean time, assuming it to be proved that, as shown in previous chapters, habit or use has the power to cause the organs concerned in it to maintain or assume such particular conformations and pliabilities as will render them easily responsive to the habitual stimulus, it follows that every new habit (or stimulus), when it is first exercised upon an organ, must be able to move that organ and do something through it in order that any differentiation or change in the organ can ever take place. In other words, if the organ cannot perform the function at all in some sort of a way to begin with, inadequately, indifferently, or badly, it can not be differentiated by the habit at all. Every function must therefore be first badly or inadequately performed by (or upon) an imperfect or-

gan badly adapted for its performance, in order that there may be a differentiation of the organ in favor of such function.

Applying this deduction to the case of the Moneron, it follows that in this animal every function is performed in some sort of way, good, bad or indifferent, that is performed by its immediate progeny or descendants. The same can be said of these descendants in reference to *their* descendants. And the same is to be said of every organ which becomes in one generation different from its predecessor of the generation before, or which undergoes modification or diversion during its own individual existence. But differentiation is not only the modification of organs from an adaptability for one function to an adaptability for another. All sorts of stimuli that influence organisms are of a compound or composite nature. Under the term pressure, we include pressures of many degrees of intensity; and touch is used to express the contact of many different sorts of objects. The impact of aerial vibrations that gives us the sensation of sound, may be infinitely varied in force and quality. The ethereal vibrations that represent the radiant energy or sunlight are likewise in great variety of length and amplitude. So the process of alimentation is a compound one involving a number of steps. Now a differentiation by which one part of an animal is habitually subjected to one sort of stimulus, and thus erected into an organ, implies that before such differentation, the part out of which the organ was constructed had been under the influence of that stimulus, and had responded or reacted against such stimulus in the performance of a function. Thus the first organ of hearing must have arisen on a part of the body which had previously become more sensitive to the vibrations of air than any other part, presumably a part more exposed to the impact of such vibrations, as the *foot* in the case of some of the Mollusks that expose no other part of the body, but generally the head, which in most animals is the most exposed part. The organ thus differentiated from an already sensitive part of the body would be itself subject to still further differentiation, since each tone of sound that strikes it would produce a different effect upon it. Some vibrations having a more acute effect on some fibres of the organ than on others, such fibres would gradually become the property of such vibrations, and finally be sensitive to such tones *only*. This as we shall see is actually the case in the vertebrate ear; the fibres of corti, to the number of some thousands, forming a progressive series of strings, each capable of being stimulated only by its sympathetic note. On the other hand, it could not be assumed that any one part of the body of a simple animal could in the first instance become responsive to the impact of sonorous waves, more than any other part. Originally all parts must have been alike, therefore all must have been sensitive to those vibrations which in the higher organisms create the sensation of

sound. I am not claiming that the simple animal possesses the faculty of hearing in the sense that a mammal does, but that the aerial vibrations that cause a responsive vibration in the fibres of the mammal ear also cause a molecular vibration through the cell of the simple animal. This vibration may be called by any name we like—a jar, a shock, a shudder, a thrill, a stimulus, or a sense. The essential fact is that in the simple undifferentiated animal this jar or shock may affect any or all its molecules alike. But the first differentiation of this stimulus is that by which one part of the animal receives the brunt of the shock and the rest of the animal is not shocked at all, or is shocked at second hand by a propagation of the stimulus through the intermediate molecules of the animal. Such differentiation as this would begin only in an animal having already a considerable development, and just as soon as the habits of the animal caused one part of the body to be constantly exposed and the rest to be constantly protected from the direct impact of the stimulus. And by the laws of habit the effect would be to increase the sensitiveness of the exposed part to the direct impact, to decrease the sensitiveness of the non exposed parts to the direct impact, but to make such parts more sensitive to a vibration conveyed *through* the intermediate molecules, and finally to cause these intermediate molecules to become more supple and pliant in the reception and conveyance of the vibratory stimulus. This process of differentiation would result in an auditory sense organ, an auditory nerve, and a ganglion.

But more than this. The stimulating vibration could not stop at the ganglion, but would necessarily pass on to the extremities of the body, through the medium of another set of intermediate molecules. Thus the muscles of the extremities would receive their stimulus at third hand, and the path of such stimulus from the ganglion to the extremity would, by habit, become differentiated into an efferent nerve. Now, in each of these cases of supposed differentiation, all the parts are removed from the direct effect of the original stimulus or shock except the one sense organ. The sensibility of that is constantly increased, but the sensibility of the other parts for the external stimulus is rendered entirely latent and ineffectual, or is perverted into a sensibility for the stimulus at second and third hand. Stated in general terms, the development of a new function in any organ or part has a tendency to obscure and render abortive any old function, and any differentiation by which one part acquires greater efficiency in any function, entails at the same time an equivalent loss of such efficiency on the other parts, by causing in them a discontinuance of the habit of performing such function. The ear of a vertebrate cannot be stimulated by a flash of light, nor the eye by a wave of sound. If the optic nerve could be connected with the tympanum of the ear, every sonorous vibration would

be conveyed to those brain cells that have been differentiated for seeing only, and the noise would be to them only a flash of light. Any accidental blow about the head that gives a violent jar to the optic nerve is falsely reported to the brain cells as *flashing lights* or *stars*, as most people know by experience.

On the other hand, where the differentiations have not gone too far the original habits of the parts may be easily renewed. Thus the differentiation of the Hydra Polyp from a simple animal has gone far enough to give him a distinct inside and a distinct outside. He consists essentially of two skin bags, one inside the other; the inner one acting as stomach and the outer one being the skin. The differentiation of these two skins is so slight that if the animal be turned wrong side out they will readily exchange offices, the outside skin being well able to digest a dinner if required. This is not only an illustration of the process but is proof of the fact of the differentiation of unlike parts from a homogeneous original. Differentiations proper, as distinguished from diversions, cannot take place except where a stimulus is of a compound nature, and where the organ or part to be differentiated is susceptible of division into parts. For example, the function of the digestion of food is quite a simple affair with the Hydra. The entrance to his sac-like stomach is surrounded with little arms called tentacles. By the rapid motion of these, when any particle of food strays within their reach, it is whirled into the bag. There it stays till all the nutritious matter is absorbed from it, when the remnant is ejected along the road by which it came in. In the Worms great differentiations have taken place. The original bag-like interior has become a tube, and is cut up into several apartments opening from one to another, through which the food is driven backward, comminuted, macerated, digested and absorbed on the way. These several operations are more or less separated, and performed in different parts of the internal tube, and the processes are more completely and perfectly performed. Yet all the functions are but the subdivisions of one function, and all the organs differentiated parts of one organ.

Differentiation implies division. Division implies previous addition or accretion. Obviously there could be no division of organs in a one-celled animal, but when there are two, one may become unlike the other.

When the protoplasm of a Moneron has become so differentiated in his descendant of the one-hundred-thousandth generation as to present to us a sense organ, a ganglion and some nerves, we, of course, no longer call it Moneron. In its original shape the Moneron could not possess these parts, and the differentiations which have supplied them have altered him out of recognition, but it is the *same line* of life, and he and his descendants are one family, whatever their names or their shapes.

From the first existence of the simplest organism it is liable to be assailed by those forces to the action of which we are to trace the differentiation of the functions of sense and their organs. Among the first of these are contact, or touch, and molecular heat, or body warmth. Contact being the most aggressive and forcible form of stimulus, it develops the first organs of sense that show themselves in the simple animal. The sense of touch is first distributed, in a greater or less degree, to the whole skin or ectoderm of the animal, since it is all more or less exposed to the stimulus of external contact. The infusoria continually batter themselves against the sides of their environment, and against each other, by the stimulation of which process, first, an ectosarc is differentiated on the outside of their protoplasm, and, second, vibratile cilia become set off from that. Next, the vibratile cilia especially, and the ectosarc generally, may be presumed to be rendered more and more sensitive through the molecular excitement. This appears to produce results in the order Flagellata, which are possessed of one or two flagella or long bristles. When we ascend to the Hydra, or fresh water Polyp, the sensitiveness of the tentacles (into which the cilia may be said to have now grown) is well pronounced. They draw in at the first alarm. Smell and taste must be regarded as subdivisions of the tactile sense. They are chemical sensations made by the contact of finely comminuted particles on a part of the mucous epithelium, or invaginated ectoderm. These senses are both of comparatively late origin. But in the lower vertebrates the olfactory ganglia are relatively very large. The sense is also extremely delicate in most of the mammals and in the birds. In the mammals, however, the relative importance of the olfactory lobes decreases as the hemispheres and the optic lobes gain greater importance.

Taste, also developed in connection with touch, is still later than smell. Among the birds there is little or none of it, and many genera of mammals possess but a faint development of it, while it is not known that the sense is developed at all among the invertebrates. Yet the intimacy existing between taste and smell is such that it is difficult to say with certainty where one ends and the other begins, and it is safe to affirm that one may make up for the partial deficiency of the other. (We will have to revert to these matters further on.)

From the experiments and observations cited in former chapters, we are at liberty to conclude that such Protozoa as Monera, Amœbæ, &c., consist merely of a union of two *vegetable* elements or principles. One is the active protoplasm of the plant liberated from the plant cell, and the other is the co-operative fungus or diastase which in the plant appears to be inseparable from the protoplasm, and which is equally necessary to assist in the digestion of starchy food in the animal. The protoplasm

of the plant thus set free to become an animal has this chance only for a livelihood ; viz., since it has cut loose from the plant where it was associated with Chlorophyl cells which had the power to gather all the starch required for the protoplasm of the plant, it must now meet with starch which has accidentally become separated from the leaves of plants, or with juices or particles more or less digested and now lying around loose. If it fail to find this food ready made it must starve to death, for it is nothing but an adventurer, a tramp. If it meet with such food it crawls over it, and while thus in contact with it, the diastase separates it into the glucoses which are then taken up by the hungry and exhausted molecules composing the animal. The case would be somewhat different if the escaped protoplasm should have some cells of chlorophyl in partnership with it, for then it would have the same resource as the stationary plant has of getting its starch from the carbonic dioxide of the air. It would have two resources, that of the chlorophyl, and also the chance of meeting ready made food. As stated at the end of Chapter 24, there are a number of animals thus equipped with the Chlorophyl cells and so having the double resource. The dependence upon ready made food involves one of two contingencies ; the food must either be brought to the animal or he must go to it. If he gets enough food by either means, or both, the necessity to use the chlorophyl function will be obviated, and falling into disuse will after a time become aborted and the cells will disappear. If the condition of the food supply requires the animal to habitually move to it, his locomotive powers will be improved and locomotive organs finally differentiated. We are not to suppose that there is any preconceived purpose in the locomotion of a protozoan any more than in the movement of sap in the stem of a weed. Heat and light constitute the motive force in the movement of the protoplasm of the plant, and so they continue to do after the protoplasm is liberated from the plant. The matter of meeting with food in its perambulations, however important to the Amœba, is purely incidental. But having met with it, if there be unsatisfied chemical affinities in any of its molecules, the food will be absorbed. As soon as the chemical affinity is satisfied by the introduction of the food, the oxygen of the air proceeds to disturb it again by seducing atoms of carbon from the molecules of the organism, burning them up and forming carbonic dioxide as an excretion. The heat thus developed in the organism becomes the electrical energy which contracts the protoplasm and causes it again to move. No doubt both the light and heat of the sun also contribute directly to this end as well as indirectly. Thus the protoplasm of the amœba constitutes a machine capable of being moved by forces outside of itself. If it be not in contact with nutritive substances, or if it lose the association of chlorophyl, this quality

of locomotion becomes essential to it and must be constantly put in practice, and as a necessary consequence become gradually improved and developed. *Observe* that what the Amœba *appears* to *do* automatically, it is in reality merely an instrument for doing, the real agent being outside of itself. Even the polarities of its constituent atoms and molecules by which they are caused to fasten themselves to each other and to new atoms in growth and renewal of tissue, are made to become operative by heat furnished directly or indirectly from the outside. Withdraw the heat till the temperature falls to freezing point and the movements of the animal are no longer possible; its affinities are no longer in operation. The principle of differentiation seems much less miraculous when it is viewed as the work of a competent external energy, than when thought of as *spontaneous*. The development of a limb or a sense organ then is not a spontaneous operation. What chance indeed is there for spontaneity in a speck of protoplasm? What could be meant by such an expression? If it means that the protoplasm has innate original energy of its own, then it would have to be admitted that such energy is in definite quantity and very small quantity at that. Consequently any activity of the organism would soon exhaust its energy and then it would be dead. According to the axioms of physics, something cannot come from nothing, nor can power originate from no-power. A mill-pond may seem to supply the water that runs the mill, but the pond would soon be dry if a stream did not constantly run into it, and but for the stream, there would have been no pond to begin with. So of the organism; what stock of force it may have by virtue of its organization was left there by the energy which organized it, and it would be exhausted by the first instant of activity if that energy did not every instant reinforce it. The form of energy concerned in putting together atoms, molecules and cells, is usually called Polar Energy; for the reason that its activity appears to be especially directed and concentrated with reference to particular points or poles of the units operated with. These poles are supposed to be the points at which the attachments between molecules, &c., are formed. There can be no doubt, in fact it is proved that the form of a mass of matter determines the position of its poles, and consequently the manner in which the polar energy shall affect it. The action of the polar currents by attaching new particles to a mass, changes its shape, and this in turn changes the direction and effect of the polar energy; just as a stream of water by encroachments upon its banks throws down materials which react to obstruct and deflect the current, and pave the way for further encroachments in another place. The movement of ethereal matter which constitutes the polar current, like the movement of water, always takes the direction of the least resistance, and the attachment of new particles to

a mass already formed, will be in the direction of the currents. This direction of least resistance is along the most *habitual* route, because along that route the molecules by way of which the current travels, are kept by it in proper position as to the direction of their poles, their axes remaining in line and not getting crosswise. Such habitual tracks of polar currents finally become differentiated into nerves in which the molecules are always better pathways than are furnished by undifferentiated tissue. The selection of the *termini* of such route governs the location of the line. Those points on the outside edges of the body of the organism, which come most into contact with the environment and are therefore the seats of activity or stimulation, become the termini. In an Amœba such points are not fixed, but are temporarily established each time a contact is formed. When some point happens to enjoy a greater amount of stimulation than others, the route leading from it across the body of the organism becomes a track of less resistance; and in an advanced descendant becomes the seat of a nerve fibre, while the terminal point develops a sense organ. When the Amœba becomes differentiated with organs, he is no longer an Amœba. The first sense organ is an organ of touch and its location is upon the part exposed and stimulated the most, and which therefore becomes the elementary limb. This sense usually remains in connection with a projecting organ as a flagellum, a tentacle, a ray, as in the star fishes, a tongue, a finger.

Locomotion being an advantage to an animal destitute of chlorophyl, it becomes a subject of natural selection and constant improvement. Natural selection, too, would emphasize the facility with which the terminal sense organ would receive the stimulations of contact, and so constantly improve it. An organism is thus built up and made locomotive and susceptible to stimulation by polar energy. Its constitution is not very well settled at first, and its locomotion is vague and indefinite. But, in the course of generations, the constant influence of this energy finally brings comparative order out of this chaos; most particles in the body become way stations on some line of communication, and have their definite and constant relationships with their neighboring particles. If the polar energy were itself uniform and unvarying, perhaps perfectly symmetrical organisms would result from its operations. But while it is to be regarded as *one*, yet, like a great river, it is full of eddies and whirlpools, rapids, cataracts, and stretches of placid and smooth-flowing current. An organism, subjected to the formative influence of the great agent, is considerably knocked about before it is finished—or, rather, it never is finished, for it continues to be harried, overhauled, and operated upon in various ways, till at last it becomes so clogged up with unassimilable foreign substances as to die of old age, or is sooner done for by some accident. But the general

tendency of the operation of the agent in the case of any given organism is to build such organism as a crystal is built, putting each additional piece in the place required by the polarities of the parts already placed. Considerable latitude is possible in doing this, as we shall see, just as there is in the building of mineral crystals under apparently uniform conditions. In any given locality where the conditions are not subject to change, generation after generation is produced without much variation, except toward the production of more perfect uniformity. This is seen in the exact resemblance for each other shown by a herd of buffalo, a flock of sheep, a drove of hogs, a flight of pigeons, a covey of partridges, a hive of bees, &c. Even in tribes and nationalities of men this is shown. It is the same in plant life. Every individual begins life as an organic crystal. Its polar points govern the energy in the disposition of its accretions. We have seen how some part of the embryo goes ahead of the rest in its development, as if it were in a favored position. But soon its growth is checked and another part is brought forward. When the second part has reached a certain stage, the first is free to go on again. Instead of being a single homogeneous crystal, the organized body, composed of differentiated parts, appears rather to be a combination of different sorts of crystals, each increasing after a fashion of its own, and each, to a certain extent, influencing and limiting the growth of the rest.

Differentiation, in its more extended meaning, may include all the variations made in the organism from the hereditary pattern, regardless of their cause. But what has been said already would seem to indicate that although all the apparently different causes in reality fall under one head they may, with propriety, be placed in two sub-classes, which are not, however, in strong contrast. One of these relates to the larval or embryonic period of life in which the organism is passive; the other, to the condition in which the animal is active. In the former, there are no reactions, or very simple ones, to complicate the direct formative action of the polar energy in placing the new materials in building the structure. In the latter, the reactions are so important and prominent that they are apt to obscure the real force behind them. Before the birth of a mammal infant such variations as are made in its structure are due to influences directly upon the mother. After the birth, the differentiations are chiefly in consequence of peculiar conditions in the environment, which cause peculiar modes of activity in the animal itself. Before they can operate upon the animal, the various forms of energy in the environment are all reduced to the polar energy, appearing in nerve currents, muscle contractions, and glandular activities, so that, in reality, the same force operates at every period of existence. A good many examples of the effect of action in differentiating

organs, have been given in former chapters, and we shall meet with others. Some of the other sort will now be given. All our rudiments are survivals in man of organs or forms which were permanent and of use in some of our animal ancestors, but useless to us. As seen in chapter 5, we carry a liberal stock of these useless and played-out appendages about with us. It occasionally happens that the development is arrested in regard to a particular part, but that such part, instead of remaining a useless rudiment, proceeds to perfect itself and to become functional at a lower stage, as it is in some lower animal form. But there are other classes of phenomena still, some of which are denominated *anomalies*, others *monstrosities*, which are to be explained on a different principle. If a man should possess a certain organ not constructed after the human pattern, but like the corresponding organ in a cow, and such organ were functional and served the purpose, it would be called anomalous, and yet it might not be strictly a case of arrested development. In the course of embryonic life we are constantly passing points at which the embryonic life of some other animal, which thus far has been identical with ours, diverges from our own and takes a different development. For example, a portion of the system of blood vessels of the vertebrates is developed from the original five gill arches. (See fig. 27.) But in none of the higher animals are all of these arches utilized, the birds adhering to and developing one part of the original form, and the mammals another, while the parts not utilized are suppressed. (See figs. 28 and 29.) Different families of mammals differentiate this development still further; the normal form of these blood vessels being different in man from that which obtains in cows or whales. When in the course of human development the embryo has reached one of these points of divergence which lead off into the developmental path of a dog, for example, we may confidently assert that nothing but its environment with its particular set of influences, makes its further progress certainly human, and insures it against switching off upon dog development, as relates to that special part. But the fact is that the environing influences of the human embryo are so nearly those of the other mammal embryos that they do not always insure a rigidly human development, the switching actually does, in a great number of cases, take place, and the man becomes, so far as the involved parts are concerned, a dog, a whale, or a bat, &c.

All this is readily explainable on the theory that the mammal germ is a crystalloid, and, when immersed in a proper solution, tends to develop along a particular line of crystallization. But its complexity and numerous subordinate polarities render subordinate modifications possible when the environing solution presents *slightly* modified conditions.

An excellent article by Dr. Francis J. Shepherd, in Popular Science

Monthly for Oct. 1884, contains a large list of abnormal forms which are found in human subjects. From this article, by permission of the Editor of the magazine, I gather some interesting facts. Some of the abnormalities mentioned will be readily referred to arrested development, in which conditions that are usually temporary in the embryo, have persisted into adult life; others belong to the class which we may call divergent crystallizations, or differentiations. Out of nearly 300 subjects dissected by Dr. Shepherd, he scarcely found one in which there were no variations from the normal anatomical structure, while many are very abnormal, having as high as thirty or forty variations in their bones, muscles or arteries. They occur oftener in Negroes and Indians than in Europeans. These variations are almost always directly comparable with structures permanent in the lower mammals. This is so generally the case as to lead to the confident inference that the most of those not thus accounted for will be as soon as comparative anatomy is better known.

An *Epiphyal bone.* This bone extends from the temporal bone of the skull, in many of the lower animals, down along the side of the neck, and connects or articulates with the hyoid or little tongue bone. In man this *Epiphyal bone* does not articulate with the hyoid but is shortened up to a projecting stick-like bone, half an inch long, called the styloid process of the temporal bone, and from the end of it to the hyoid bone there extends a fibrous cord or ligament. Dr. Shepherd has a human skull of low type in which the styloid process is a true epiphyal bone, 3½ inches long and which, in life, did articulate with the hyoid as in the lower animals. This same skull has, on the left side behind the mastoid process of the temporal bone, a stout, bony spur more than ¾ of an inch long, which has a downward direction and articulates with the first bone of the vertebral column. This is very rare in the human being, but is regular and normal in most graminivorous and carnivorous animals, being especially well marked in the horse, pig, sheep, and goat; and in them it gives attachment to strong muscles which move the head on the trunk. It is called the paramastoid process.

In Crocodiles, Birds, and the three-toed Sloth, there are always ribs attached to the cervical, or neck vertebræ, and in Crocodiles, Alligators, and some other animals, there are always ribs attached to the lumbar vertebræ. But these are not normal to man. The human embryo, however, always has a rib on each side connected with the seventh neck vertebra. Ordinarily, before the fifth year it becomes blended with the ordinary transverse process, but occasionally this rudiment goes on developing till it becomes a more or less perfect cervical rib.

Lumbar ribs are also occasionally found. These supernumerary ribs are no doubt due to arrested development.

The *supra-condyloid* process is another feature belonging normally to most of the carnivores, including the cave bear, but not the rest of the plantigrades; and to the monkeys, lemurs and sloths. This consists of

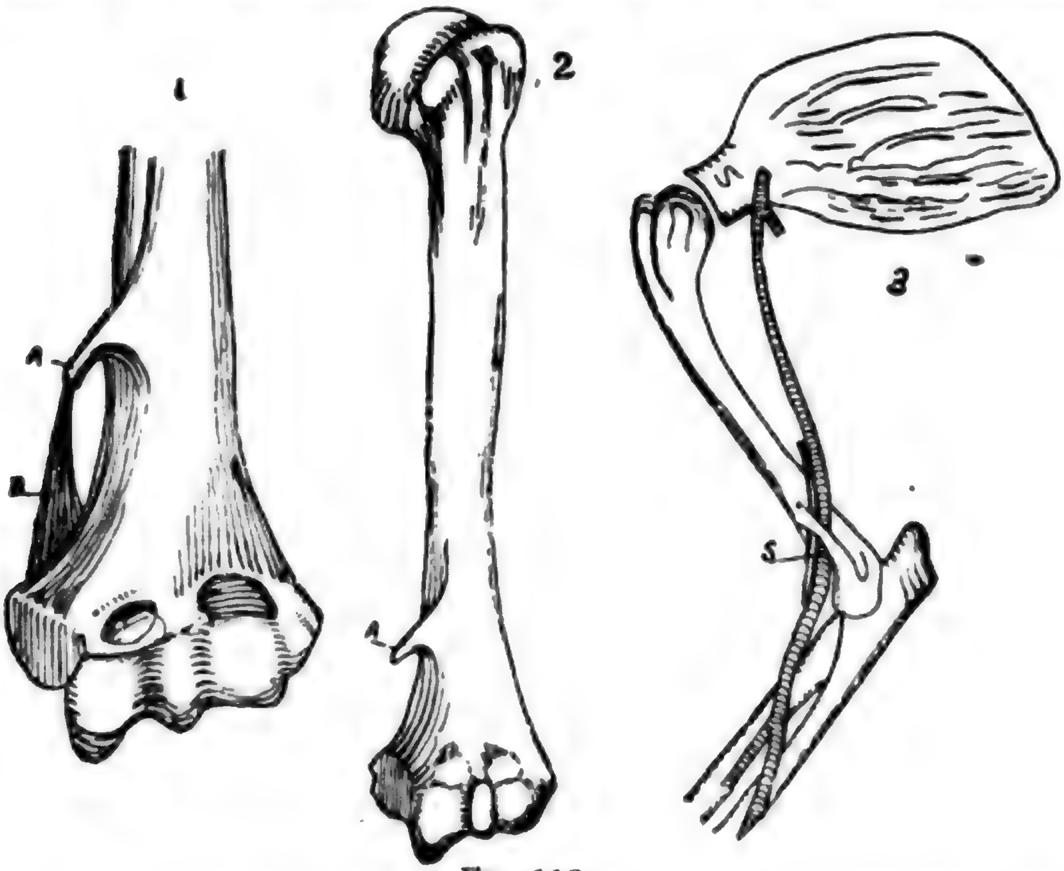


FIG. 112.

FIG. 112.—2—Humerus of Man showing the *Supra Condyloid* process A—a rudiment. 1—Lower part enlarged showing A the supra condyloid process, and B the ligament which completes the foramen in 3 per cent. of human subjects.
3—Bones of fore limb of Cat, showing the foramen in use.
s—Blood vessel and nerve passing through. (*After Struthers*.)

a hook-like process of bone on the inner side of the lower end of the humerus or arm-bone. From the lower point of the projection, a ligament passes on down toward the joint and is attached there to the side of the bone, thus forming an opening or foramen through which, in the lower animals mentioned, the great nerve and blood-vessel of the fore limb pass. This foramen appears in about three per cent. of human skeletons, and is of no advantage to man.

In men there are two prominences on the upper part of the thigh bone, called respectively the greater and less trochanter. They afford attachment to rotator muscles of the thigh. In certain animals there is a third trochanter, and it gives attachment to the great gluteus muscle. It is very large in the Horse and Rhinoceros and is found in others. It is found in a few human skeletons, the per cent. varying in different countries. Out of 40 skeletons of Swedes 15 had it, of six skeletons of Laplanders it was possessed by four. But Dr. Shepherd found it in only one per cent. of Americans.

"In the human wrist are eight small bones called carpals and arranged in two rows; occasionally between the two rows we have a ninth bone called the "os centrale." In the human foetus a rudiment of this bone is always to be found at an early period, but it usually entirely

disappears by the fourth month of foetal life. The Gorilla and Chimpanzee ordinarily have only eight carpals as in man, but in the Orang and most of the lower apes and in some of the Rodents there are always nine. So that when we have this reversion it is to a type below the Chimpanzee or Gorilla.

Every naturalist now admits that the various stages of development of an animal as well as its specialized parts are found to correspond with permanent conditions of animals lower in the scale. A good illustration of this is seen in the development of the human heart and blood-vessels. In the early stages of development we have a heart with a single cavity connected with a vessel at each end as in ascidians; later on the blood-vessels consist of a series of arches which go to the gills or bronchial clefts as in fishes and amphibia, while the heart consists of two chambers separated by valves, and is placed forward in the neck. The gill arches now partly disappear, and though the circulation still remains single as in Reptiles, the heart cavities are beginning to be separated into two distinct systems. Soon a double circulation is required by a complete separation of the heart into right and left. The right heart propels the venous, and the left the arterial blood. At this period the condition is identical with that of birds; at last the true mammalian type of heart and blood-vessels develops and remains permanent. The arrangement of the blood-vessels going to and from the heart varies considerably in different mammals. In man the rule is for the great artery, carrying the blood from the heart to the general sys-

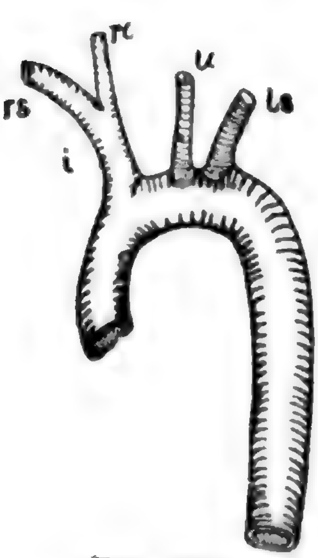


FIG. 113.

FIG. 113.—Normal *aortic arch* in man.
rc.—Right carotid artery. *lc.*—Left carotid artery.
rs.—Right subclavian artery. *ls.*—Left subclavian artery.
i.—Innominate artery.

tem, to give off three main branches, named the innominate, left carotid and left subclavian. These are distributed to the head and the two arms; the main vessel, or aorta, curves downward and distributes blood to the trunk and lower extremities. These branches are now known to be derived from certain of the original gill-arches which persist, (See figs. 27, 29) and when any variation in their arrangement takes place it always occurs in the line of some of these gill-arches; that is, some of arches persist which usually are obliterated. Nearly all the variations occuring in these large vessels in man are found to be the regular condition in animals lower in the scale; for instance, sometimes only two branches are given off instead of three; each of these again dividing into two, one for the head and one for the arm of that side. (See fig. 114 B.) This is the usual arrangement in the bat, porpoise and dol-

phin The commonest variation of the aortic arch is where the innominate gives off the left carotid as well as the right, and so supplies both

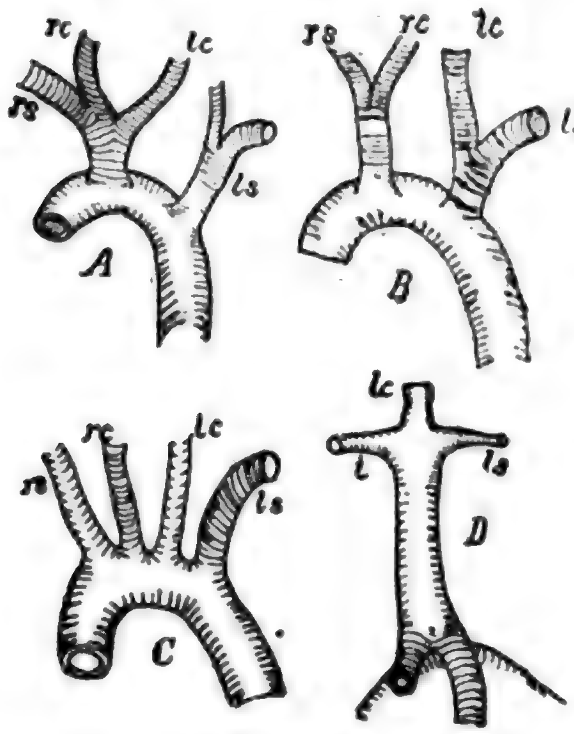


FIG. 114.

FIG. 114.—Four specimens of Human Anomalous formations of the *aortic arch* and its branches.
rc, lc.—Right and Left carotid arteries, going to the head.
rs, ls.—Right and left subclavian arteries, going to the arms.
i.—Innominate artery.

sides of the head (See Fig. 114 A), the artery supplying the left arm coming off as usual. This is the normal condition in Apes, Bears, Dogs, and all the feline tribes (Lion, Tiger, Cat, Leopard, &c. See fig. 115 D). In some rare cases in man one branch only comes off from the aortic arch, and this again divides into the various arteries supplying the head and arms. In Horses and other solipeds, we see this form of aortic arch. (See fig. 114 D and 115 A.) Again, the branches may all be given off separately from the arch, as is the arrange-

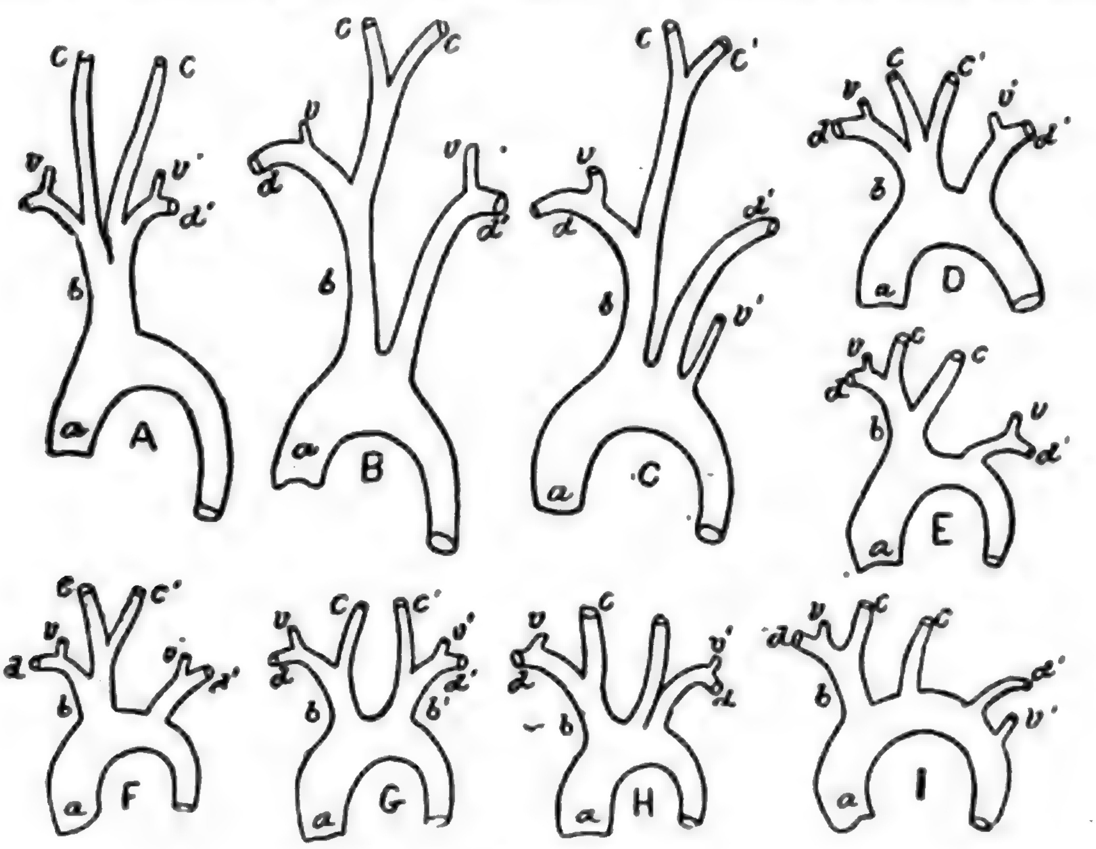


FIG. 115.

FIG. 115.—Origin of Arteries from Aortic Arch in some Mammals.—(*Owen.*)
A.—Ox. B.—Lama. C.—Giraffe.
D—Lion. E.—Otter. F.—Gibbon.
G.—Hedgehog. H.—Man. I.—Dugong.
a.—Main Aorta. [references same in all.
b.—" Anterior Aorta " of Veterinarians or " innominata " of human anatomy.
c.—Right Carotid artery. c'—the left.
d.— " Brachial artery (to the right arm). d'— " "
v.— " Vertebral artery, or right Thoracic v'— " "

ment in the Walrus." (See Fig. 114 C.) "I have three times met

with a rather rare anomaly of the great *veins* going to the heart from the upper part of the body. The usual arrangement in man on each side, is for the great vein of one arm and the corresponding side of the head to unite and form a single trunk (*brachio-cephalic*), so we have two large venous trunks, one on each side. These two trunks then join to

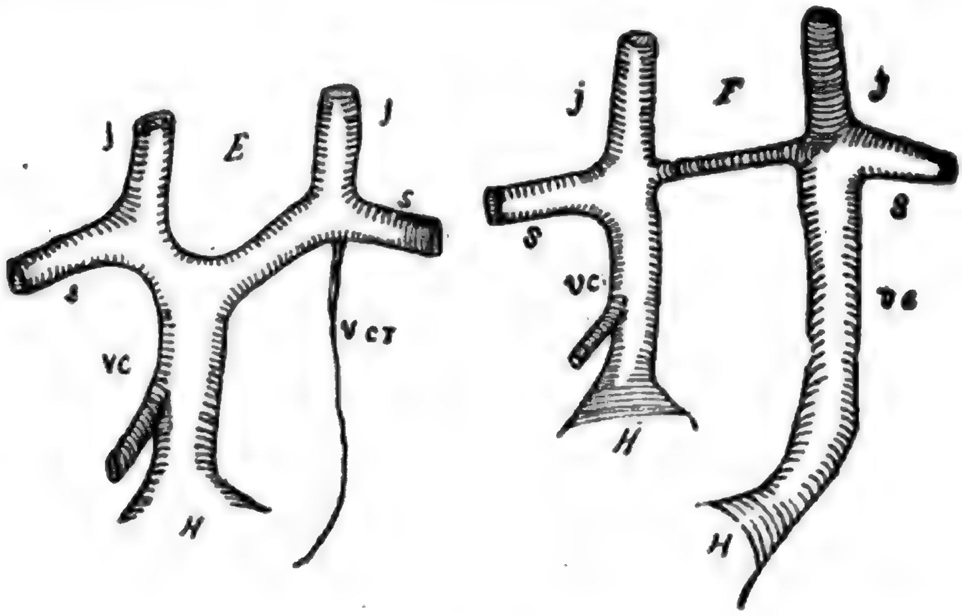


FIG. 116.

FIG. 116.—E.—Normal Arrangement of the Vena Cava and branches in the Human Adult.

H.—Right Auricle of the Heart. *vc.*—**Vena Cava.**

jj.—**Jugular veins from the head.** *ss.*—**Subclavian veins from the arms.**

vcr.—**Remnant of the Foetal** *left vena cava.*

F.—Abnormal arrangement in which the foetal left *vena cava, vc, persists* **through life.**

form a single large vessel, called the superior vena cava, which empties its blood into the right side of the heart. (See Fig. 116 E.) It occasionally happens that the great venous trunks formed by the veins of the arm and head of each side do not unite to form the superior vena cava, but each continues its downward course and opens *separately* into the heart. (See Fig. 116 F.) On studying the development of the blood-vessels, we find that in early foetal life this condition of affairs exists, but after a time a transverse branch forms between the two trunks. This branch gradually enlarges, while the left trunk shrivels up and at birth is only represented by a fibrous cord. This anomaly of the veins we find then, is a persistence of a usually transient foetal condition in man, and also that in all birds, and many of the lower mammals, it is the permanent condition."

"In man the skin muscles are very feebly developed compared with those seen in many of the lower animals. The only remnants of these in man are the muscle which wrinkles the forehead (*occipito-frontalis*), the muscle immediately under the skin covering the side of the neck (*platysma myoides*), and the *palmaris brevis*, a little bundle of muscular fibres in the palm of the hand." (There is one other piece.) "Not unfrequently remnants appear abnormally in other situations, as over the breast, in the arm-pit, on the back, &c. The skin muscles are well

developed in those of the mammalia which have loose skins, as, for example, the hedgehog, porcupine and porpoise. In the hedgehog, when the muscles contract, the animal becomes rolled up as in a bag of muscles. The sportive gambols of a school of porpoises are effected by an abundant supply of these skin muscles; in the horse the skin muscle is called the *panniculus carnosus*, and everyone who has seen a horse twitching its skin to get rid of troublesome flies, will easily understand how serviceable it is to that animal.

"In all human beings there is a small muscle going from the *coracoid*, a hooked process on the upper end of the shoulder-blade, to the inner side of the arm-bone, about the junction of its upper and middle third. Sometimes this muscle is continued down to the lower end of the arm-bone; or, again, it may be quite short and attached to the bag of fibrous tissue covering the shoulder-joint. On referring to the anatomy of the lower animals it is found that both these varieties exist normally but in a much more highly developed state; they are especially well seen in animals which use their fore-limbs for digging, climbing or swimming. In them the muscle is of large size and reaches to the inner edge of the lower extremity of the arm-bone. In man, when it reaches thus far it is only rudimentary and of no use. Another muscle, which I have seen in about three per cent. of human subjects, is a small one which goes from the breast-bone to the upper end of the shoulder-blade. This muscle is well developed in animals which have no collar-bones; it reaches its highest development in the horse, pig, hippopotamus and elephant. It is also seen in the guinea-pig, Norway-rat and wombat. It is quite rudimentary when it exists in man, and serves no useful purpose.

"In man, near the elbow-joint and lying close together, are two muscles going from the upper to the lower arm; one in front (*brachialis anticus*) which helps to bend the elbow, and the other to the outer side (*supinator longus*) which supinates or twists the fore-arm outward. As a rule these muscles are quite distinct, though they lie side by side; but in about one per cent. of cases they are joined together by muscular fibres. This is the normal arrangement in apes and monkeys, the union of these two muscles aiding them greatly in twisting their bodies when hanging by their fore-limbs to the branches of trees. Again, in apes the muscle forming the posterior fold of the arm-pit is always prolonged down to the prominence on the back of the elbow. In the long-armed apes this muscle is especially well developed, and serves to swing the whole arm rapidly and powerfully forward—a movement which is of the greatest importance for dexterously grasping remote branches while in the act of climbing. The same prolongation of this muscle is occasionally seen in man, though in a much less developed state, and

serves to remind him of the arboreal habits of some of his not very remote ancestors." Another muscle always present in the Gorilla, Orang and Chimpanzee, is found in about three per cent. of human subjects. It connects the upper neck bones to the collar-bone. It is used to raise the latter and is called the *levator claviculæ.* There are other muscles of large size and important function in the Lion, Deer, and others, which go from the back of the head to the collar-bone or shoulder-blade, and are used to pull the shoulder forward. Useless fragments and rudiments of these are sometimes found in man.

In the marsupials, Kangaroo, Opossum, &c., a large muscle is attached to the marsupial bone, and running forward is attached at the other end to muscles in the anterior wall of the abdomen. Its use is to control the pouch. About *one-half* of human subjects possess a small rudiment of this great muscle, and a short spur on the haunch-bone, to which it is connected, is the *rudiment* of the *marsupial bone.* This bone is also found in other animals beside the marsupials, but is to them of a different value, if not rudimentary.

In man the origin of the *flexor brevis* muscle of the foot is normally upon the heel-bone, and its insertion is by four small tendons in the four small toes. In a few men and in most apes, (Gorilla not included) only the part of this muscle which works the second and third toes has its origin at the heel-bone; the part which flexes the fourth and fifth being attached to the tendon of the long flexor (Flexor longus digitorum pedis).

There are occasional anomalies in the internal organs; the liver may be "degraded," that is, divided into a number of lobes, as in the Gorilla, while two is the normal number in man. "The spleen is often deeply notched and multiplied, as in the case of some of the lower animals." In the human *fœtus* the *uterus* is *double* till about the fourth month, imitating in this respect the adult marsupials and some other mammals. Occasionally this double uterus, instead of being developed into a single one, persists into the adult period and through life. "In the *brain* of no animal except man and the apes, does the *cerebrum* entirely cover up the *cerebellum.* In the horse, and most mammals, the cerebrum and cerebellum lie in the same plane, the former anterior to the latter." Dr. Shepherd saw the brain of an idiot, in which the fissures of the cerebrum were of the confluent kind, as in the pig, &c., and the cerebrum did not cover the cerebellum. The weight of this brain was *only sixteen ounces.* (Pop. Science Monthly, Oct. 1884.) From the foregoing we get some idea of the great number of small imperfections there are in most, if not all, *human crystals*—and the list is by no means exhausted. There are many curious variations in the formation of various viscera amongst men, and the lower animals as

well. By referring back to fig. 67 the position of the spleen is seen to be indicated at the right of the stomach (the *left* with reference to the body), and the duodenum at the left. The *pancreas* (not shown) lie behind the stomach and extend from the spleen to the duodenum. The position of the liver and gall bladder is above and to the left of the duodenum. Each has an outlet duct which unite and form the tube marked *a* in the next fig.

In the birds the *pancreas* are *two* in number, sometimes *three*. In some of the lower mammals there are likewise two or more pieces rather loosely connected together. All of them empty their secretions into the *duodenum*, either by separate ducts or the ducts from the different pancreatic bodies join each other and unite with the duodenum or with the bile duct from the liver. In man normally the pancreas is

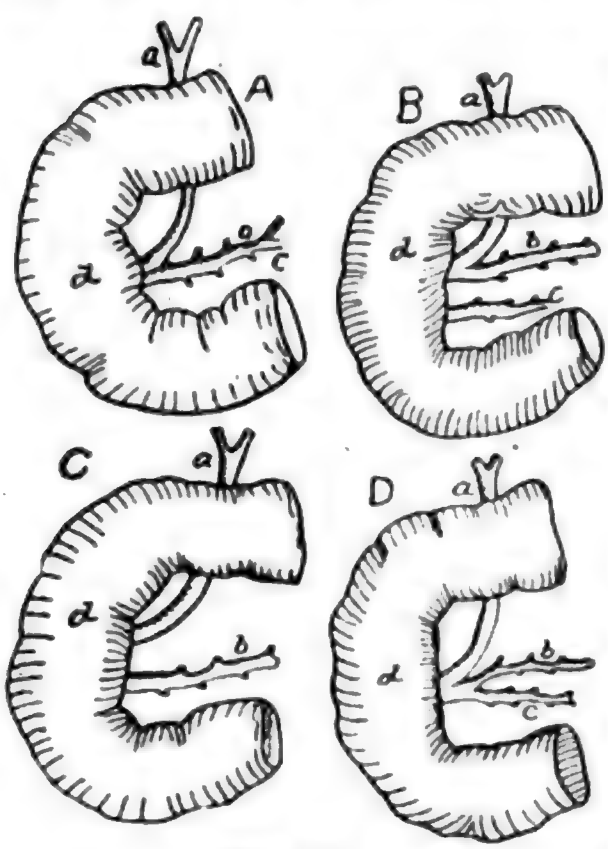


FIG. 117.

FIG. 117.—Four figs. to show anomalies in the connection of the *pancreas* with *duodenum*. (*Owen, after Hyde Salter.*)
A.—Normal. B, C, D.—Anomalies.
a.—Bile duct from the liver.
b.—Duct from the larger or head portion of the pancreas.
c.—Duct from the smaller tail end of pancreas.
d.—Duodenum.

only one gland extending from the spleen to the duodenum, but it is sometimes divided into two parts, as in the lower mammals. In man, the end of the pancreas next the duodenum is the larger, and is called the head; the end next the spleen is the tail. The pancreas is traversed by two ducts for carrying its secretion. In fig. 117, *b* and *c* represent these ducts. Normally, these two join each other, as shown in the fig. marked A, and the one thus formed then passes on to the side of the *bile* duct, *a*. These two run side and side till well within the several walls of the duodenum, where they unite in a sort of bulbous chamber called an ampulla, from which there is a common opening into the duodenum. In the anomalous case, marked B, the main pancreatic duct, *b*, proceeds as usual in company with the bile duct, *a*, while the duct, *c*, makes an entirely independent connection with the duodenum. In the case marked C, which is not so common as B, the main duct, *b*, after receiving *c* proceeds to the duodenum independently of the bile duct *a*. In the case of D, which is still more rare, the duct, *c*, besides attending to its own business, receives some of the branch ducts normally belonging to *b*, thus becoming a tube equal to *b* in size, and the two unite and then join *a* as usual. (*Quain.*) The pancreas varies

greatly in size and weight. Its weight will average about 3 ounces, but it is, in some cases, no more than 1½ ounces, in others as much as 6 ounces. (*Owen, Comp. Anatomy.*)

The *Spleen* varies in size more than any other organ in the body; and this not only in different subjects but in the same at different times, as ascertained by percussion. Its size is from 5 x 3 x 1 inch to 5½ x 4 x 1½, in health. Its weight may vary from 6 to 12 ounces, but in certain fevers it is much enlarged, often weighing 18 or 20 pounds. "Small, detached, roundish nodules are occasionally found in the neighborhood of the spleen, similar to it in substance. These are commonly named accessory or supplementary spleens (*splenculi lienculi*). One or two most commonly occur, but a greater number, and even up to twenty-three, have been met with. They are small rounded masses varying from the size of a pea to that of a walnut. They are usually situated near the lower end of the spleen, either in the gastro splenic omentum or in the great omentum." (*Quain's Anatomy*, 2-639.)

The *proper position of the Kidneys* is on either side of the backbone opposite the lowest dorsal and the highest two or three of the lumbar vertebræ, the right one a little the lowest. But they vary in position, sometimes being found even in the pelvis. They vary in shape, sometimes one being very small and the other proportionally enlarged. "Instances are now and then met with in which the two kidneys are joined by their lower ends across the front of the great blood vessels and vertebral column. The conjunct organ has usually the form of a horse-shoe. Sometimes two united kidneys are situated on one or other side of the vertebral column in the lumbar region, or, but much more rarely, in the cavity of the pelvis. In other very rare cases *three* glandular masses have been found, the supernumerary organ being placed either in front or on one side of the vertebral column or in the pelvic cavity." (*Quain.*)

Sometimes the *development of the Liver* is arrested and it retains the rounded form it has in the fœtus, and sometimes it does not divide into lobes as it should. On the other hand, it is sometimes found divided into several lobes; in one case as many as *twelve.* Some of the lower animals have such a liver. "A detached portion, forming a sort of accessory liver, is occasionally found appended to the left extremity of the liver by a fold of peritoneum containing blood vessels." In some cases there is *no gall bladder*, but instead there is a dilation of the liver duct somewhere along its course, or in the liver itself. In some cases the gall bladder is irregular in shape, or partly divided, either crosswise or longitudinally. "Direct communications, by means of small ducts (named hepato-cystic) passing from the liver to the gall bladder, exist regularly in various animals; and they are sometimes found as an unusual formation in the Human subject." (*Quain.*)

The *Superior Thoracic artery* arises from the axillary artery, or *sometimes* from the *acromial*—a branch of the axillary. It sends numerous branches to the Pectoralis Major and P. Minor muscles. "*In some* subjects there are *two* or *three* external superior thoracic arteries." (Med. Dic.) The *external mammary arteries* vary in number, *usually* four, according to Neil and Smith, and they arise singly *or together* from the axillary artery. (They are not particular.)

The *mastoid artery* (branch of carotid) is *irregular* and *uncertain* in its origin. It supplies the muscles and glands of the neck. *Nerves too:* Thus the anterior (efferent) nerves of the *first cervical* pair are sometimes *absent*. In this case there is a supply of fibres from the spinal accessory or the hypoglossal, or both. (*Carpenter's Physiology, 461.*)

Case of deficient brain: The middle part of the *fornix* and all the *septum lucidum wanting*, and the *corpus callosum* reduced to a mere rudiment one-fourth of an inch long. The person was defective in forethought, &c., but was as intelligent as the average. (*Carpenter*) (For description of these parts see chapter on Brain.) The *carotid nerve sometimes* forms a small gangliform swelling on the under part of the artery in the cranium, called the ganglion *of Laumonier*. *Accessory* of *parotid* gland *sometimes connected with parotid*, sometimes not. *Foramen cœcum sometimes* found in the *ethmoid* bone and admits a small vein from the nose. (Neil and Smith, 29 Anatomy.) Ethmoidal arteries are two in number—the anterior arises from the ophthalmic artery, the origin of the other *varies*.

There are considerable variations in the *muscles* of the *face*. (See fig. 66.) The *zygomatic minor* is *often* wanting, and its lower terminus, or insertion in the upper lip, is often abolished and the insertion made in the fascia of the cheek or in the zygomatic major. Not unfrequently the muscle is double. The z. major, too, is sometimes double, and in other cases wanting altogether. The *risorius*, or laughing muscle, is also often absent, and so is the *pyramidalis*, which draws up the skin of the nose. The variations in these muscles must cause variations in the *expression* of the same emotional states.

Supernumerary nipples are of rather frequent occurrence. Their usual situation is below and toward the middle from the normal nipple, but sometimes they are above and outside, and occasionally they are found on the abdomen. As a rule the left breast is more developed than the right, and the extra nipple, when there is one, occurs on the left side oftener than the other. This is accounted for from the circumstance that the left nipple is used more than the other because the child is carried on the left side so as to leave the right hand of the mother free. Moreover, when a nipple, or mammary gland, is missing or defective, (amastia) it is usually the right one. In 104 females,

according to Dr. Bruce, 5 had extra nipples, and out of 207 males there were 19 such cases. The abnormality, it appears, is thus more common to the male sex. Dr. Dunglison mentions the case of an athletic man 22 years old, who came in 1849, to the Jefferson Medical college of Philadelphia, with his left mamma full of milk, for which he could not account. In 1837 there was a colored man in Maryland, who was then 55 years old, and who possessed completely formed large mammæ, projecting fully seven inches from his chest with large and well formed nipples. He had for several years served as wet nurse in the family of his mistress. By applying a child to his breasts a supply of milk could be developed at any time, if he should happen to be "dry," and the secretion once started was not easy to be arrested. Yet he was a perfectly formed male. (*Carpenter, 617.*) The men of some of the Pacific islands have large breasts precisely like those of the women, and foreigners, judging by that mark, have sometimes mistaken them for women; with amusing results. (*Austin.*)

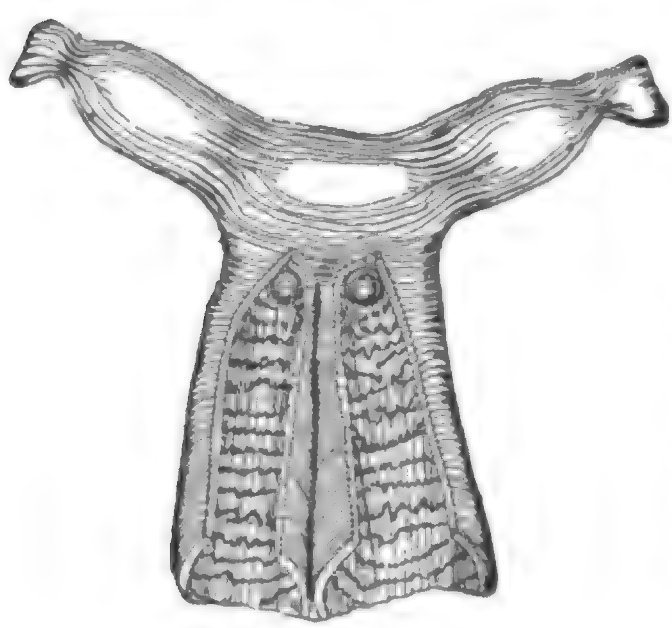


FIG. 118.

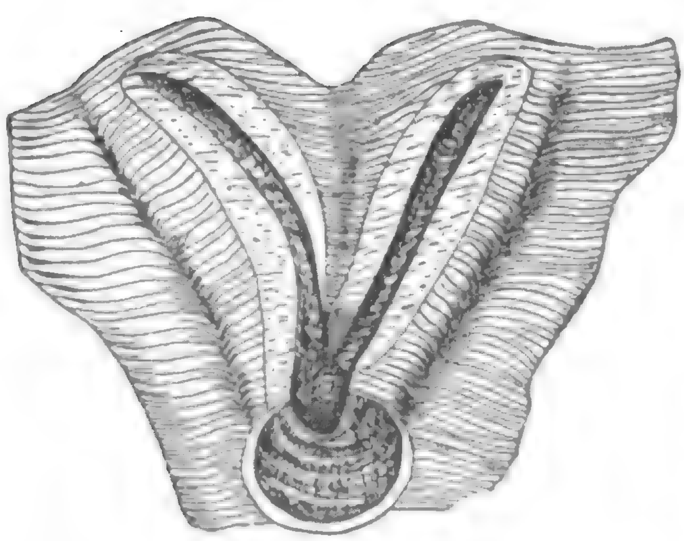


FIG. 119.

FIG. 118.—Double uterus and double vagina. *Human anomaly.* Development arrested at the Marsupial stage. Compare with Fig. 80.

FIG. 119.—*Uterus Bicornis. Human anomaly.* Development arrested at the Rodent stage.

Velpeau states that cases of double uteri are so frequent that new examples are met with every year. A septum or partition often occurs, starting at the top and extending downward, dividing the organ sometimes for only a short part of its length, at other times descending as low as the neck of the uterus, completely dividing the organ into two. A case is cited by De Graaf in which the separation includes the vagina also, the development being arrested at the stage of the Marsupial type. Other cases of double vagina are reported. There is also a case mentioned in which there is a short, common cavity, or "corpus," intervening between the cornua of the uterus and the vagina, the development being that of certain Rodents.* The septum in the uterus has sometimes an opening in some part of it, allowing communication between the two cavities, showing an intermediate stage. The septum in the vagina sometimes gives it "the appearance of two united cylindrical canals, each having a *hymen*, as occurred twice to Callisen and once to Eisenman, or a single opening, as noticed by Bartolin and Haller, some-

* Arthur Farre—Uterus and its appendages. Cyclopedia of Anatomy Supplement, 1859.

times it exists only above and below, and allows the two vaginæ to communicate with each other about the middle or near the neck; most frequently, as remarked by Majocchi, Bœhmer, Cassan, and others, it does not reach to the vulva, and, further, it is, in general, only the continuation of a similar disposition of the womb." (Velpeau's Midwifery, 115.)

The normal and usual change which takes place in the *lungs at birth* afford a first-class example of the modifying effect of an environing force upon an organic machine fitted to be moved by it. Before birth the lungs, which have been built up by heredity, according to a certain pattern, weigh one seventieth ($\frac{1}{70}$) of the whole body. They are very small, of a "compact, heavy, granular, yellowish-pink, gland-like substance," with specific gravity heavier than water, and absolute weight of about $1\frac{1}{2}$ ounces. The admission of air to the lungs immediately changes their substance into a loose, light, rose-pink, spongy structure, their absolute weight rises to as much as $2\frac{1}{2}$ ounces, and relative to the body $\frac{1}{35}$ or $\frac{1}{40}$, and the specific gravity sinks to one-third that of water, their size correspondingly expanding. (*Quain.*) The changes wrought by the air in this organ in a few hours almost equal those of all the previous months. There appears to be a sort of preparatory adaptation of the young animal to this sudden exposure to the direct impact of a force which had before affected it indirectly.

A good many examples of retrogressive adaptation have been given, enough to prove the influence of the environment in effecting adaptations, even if it has to cause an "advance backward" in order to accomplish it. The limb of the Dolphin shown in fig. 120, is a case in point. The thumb and the fourth and fifth fingers are relatively greatly reduced, and so are the arm bones in respect to their length. This animal is descended from a land mammal and has become adapted to a sea life. But though reduced as to legs, the dolphin has a highly developed brain.

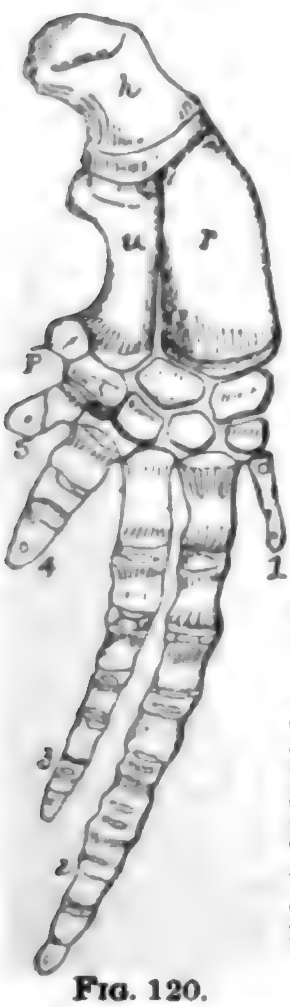


FIG. 120.—Right fore limb of Dolphin.
h.—Humerus.
r.—Radius.
u.—Ulna.
1.—Thumb.
2, 3, 4, 5.—Fingers
p.—Pisiform bone. Compare with fig. 69.
(*VanBeneden & Gervais.*)

FIG. 121.—Foot of *Night-jar* or *Goat-sucker*, showing its fine comb. The same sort of an appendage is developed on the foot of the common *Barn Owl* and the *Heron* and *Bittern* species. These are all *lousy birds*, a fact which suggests the use and causes of the development of the instrument. (*After Owen.*)

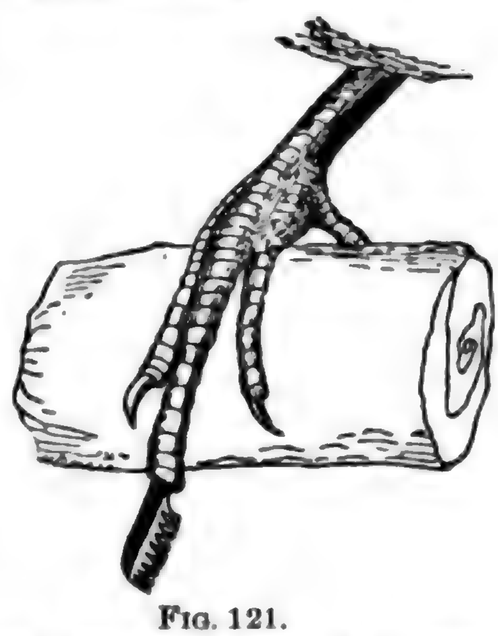


FIG. 120. FIG. 121.

The *pisiform* bone shown in this figure, and several others, is a carpal bone said to have originally belonged to a *sixth finger.* We have

occasional human cases of reversion to hands and feet, having six digits. No mammal has six digits, so the reversion must be to a type below the mammals. Ought we not to class the curious development of the Goat-sucker's fine comb as a progressive one? (Fig. 121.)

It is said that Bucephalus, the celebrated war-horse of Alexander the Great, in addition to having a head like an "ox," by which he got his name, was a *three-toed* animal. If so, his feet reverted to the type of those of the horse of Miocene Times. (See fig. 73.)

FIG. 122.

FIG. 124.

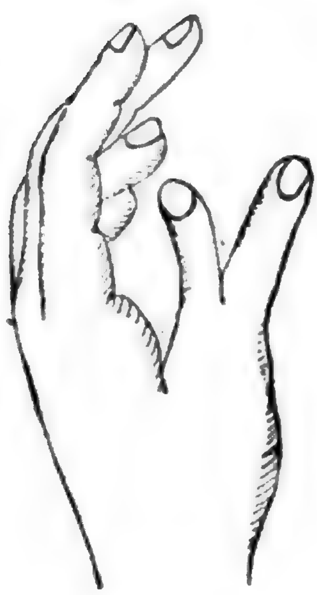


FIG 123.

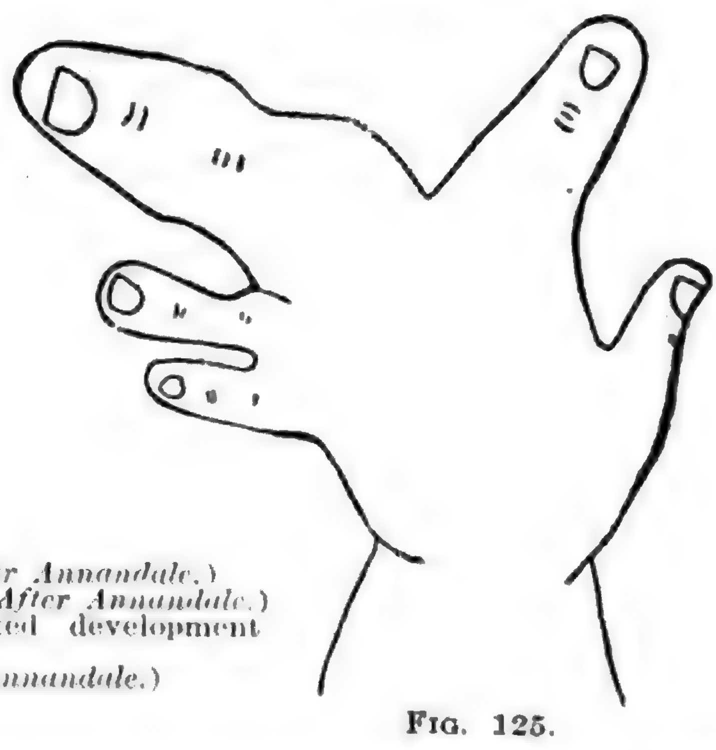


FIG. 125.

FIG. 122.—Supernumerary *Toe.* (*After Annandale.*)
FIG. 123.—Supernumerary *Thumb.* (*After Annandale.*)
FIG. 124.—*Webbed fingers.* Arrested development (*After Reeves.*)
FIG. 125.—Monstrous hand. (*After Annandale.*)

There are many sorts of monstrosities which probably must be referred to a tendency to crystal-variation. There are monsters in which some part of the body is wanting or is developed too much. There are others in which parts which should be separated are coalesced; others in which parts are separated by a fissure which ought to be joined together; others still in which normal openings never are opened. This

might be arrested development. Others in which organs are excessively developed.

The distinction of *Species* was, by the old naturalists, thought to be an everlasting and impassable barrier or fence separating the tribes of animals and forming the limits within which the children might differ in form from their parents, and new varieties thus be set up, but within which the *species* must forever remain, as they claimed they always have remained from the day of their creation. This theory contemplates a supernatural creation of all the animal tribes in pairs, each pair the originator of a species. This theory is rendered impossible in view of all the facts that have been cited showing the modifying and selective agencies at work on the organism, and the modifications that have been actually accomplished by them under human observation. But there is still another class of facts that may be said to finish the subversion of the ancient theory of species, and that is the facts of *hybridism*, or the mixing of species in reproduction. Hundreds of such mixtures are known to have taken place between animals of various species, and we are left without the slightest assurance that the blood of any species has, in a state of nature, remained pure for many generations. The following are some of the crosses known to have taken place either in a state of nature or in captivity to man: *Cynocephalus Mormon*, or mandrill,[1] and *Macacus Cynomolgus*, or hare-lipped macaque (baboon); rabbit and hare; tiger and lion; leopard and jaguar; polar bear and brown bear; masked pig of Africa and domestic Berkshire; dama vulgaris[2] and dama mesopotamica; equus onager (wild ass) and equus hemipus; Burchells zebra and horse; Burchells zebra and ass; Burchells zebra and equus *hemionus*, or Dzegguetai; polecat and ferret; wild cat and domestic cat; African leopard[3] and black panther of Java; Yak and common cow; bison and common cattle; dog and jackal; dog and wolf; sheep O. musimon and O. cycloceros; deer, C. Virginianus and C. macrotis; goat and sheep[4]; [5]deer and sheep; Bactrian two-humped camel, and Arabian one hump dromedary; modern pigeon and turtle dove; greenfinch and goldfinch. Different species of ducks with each other, as the mallard with the pintail; different species of snakes; of trout with carp; many insects, as hawk moths with several kinds of peacock moths, &c. Of the foregoing many of the hybrid products are in themselves fertile, and would almost certainly thus originate new species. And, as before said, we have no assurance that many species have not already arisen so.

[6] It is proved that hybrids are not merely copies of their parents, taking some of their characteristics from one and the rest from the other, but they always, while partaking of the parental characteristics, also take on others foreign to either parent. The mule and hinny are almost as unlike each other as are the ass and horse. We may regard the embryo as a crystalloid body made up of two sets of complemental elements, one set of which is furnished by each of the parents; and as receiving from the mother the necessary materials for its growth, as the crystal gets the materials for its growth from the solution in which it is immersed. Obviously in every cross, the crystal being the result of a new combination of complemental elements, it differs from the accustomed type. We have seen that different organisms will grow in the same nutritive solution or infusion, but will become more or less modified themselves. There are two possible crosses, such as the two from which the mule and the hinny result, so that the union of any two tribes may produce two hybrids quite different from each other and from their parents. If these hybrids are fertile, and they often are, in a few generations they might set up for species with their parent stocks as varieties.

In view of the foregoing it is no surprise to learn that naturalists have great difficulty to draw close and definite lines between species. They not only grade into each other until the distinctions become too slight to justify different names, but the species persist in crossing back and forth over every line that is drawn; those varieties near the line possessing qualities on both sides of it, related to a species on this side the line by resemblances of one kind and to a species on the other side by resemblances of another kind. The Editors of Cuvier say in regard to the classification of the cat tribes "That it is quite impossible to subdivide the genus *Felis* into definite sections, and that every attempt of this kind hitherto made has consequently proved a complete failure; the transition into the Lynxes is most gradual, and the spotless species, as the Lion, Puma, &c., are *marked like the rest when young.* Those species, however, which affect the open country, as the Lion and Leopard, have the pupil of the eye contracting to a *point*, whereas in those which inhabit forests, as the Tiger and domestic Cat, the pupil closes

[1] Semper, 353. [2] A rhinoceros the size of a rabbit.
[3] The *word* Leopard is itself a hybrid (Leo, *lion*; Pardus, *panther*).
[4] Buffon. [5] Nott & Gliddon. [6] Semper.

to a vertical line, permitting thus, when least dilated, a full range of vision direction in which these animals chiefly watch for prey." Observe that the only important anatomical distinction named is one that crosses the lines of species, and depends on a habit of the environment common to several species. The same difficulty is found in settling the boundary between the saurian (lizzard-like) and ophidian (snake-like) reptiles. A part of Cuvier's sixth family of saurians grade into the first family of ophidians. And they also grade backwards into the third family of saurians—the Iguanas. So that from the Iguanas (lizzards) to the Orvets (snakes) is an uninterrupted series of graded transitions. (Cuvier's Animal Kingdom, 267.)

The difficulties of classification are so considerable in many cases that naturalists often disagree as to the species and even to the genus of an animal. The species and genera of mollusks, in particular, run into each other in the most perplexing manner. The same thing is true of plants. The species may be crossed, and are crossed in many ways, and have been and continue to be modified constantly by new conditions of soil, climate, cultivation, &c.

CHAPTER XXXIII.

ORIGIN OF SEX.

Herbert Spencer has pointed out that in the growth of a cell the necessary nutrition, respiration and excretion must be through the cell walls, and that the surface of the cell wall is proportionately less in a large cell than in a small one. The diameter of a sphere being one, its surface will be 3.14, and its cubical contents 0.52, but if the diameter be 2, its surface will be 12.56 and its contents 4.18; that is, by doubling the diameter, the surface is increased four fold and its contents eight fold. At this rate the mass of the cell will soon become too great to get its nourishment through the surface, and when that point is reached, growth must stop or greater surface must be obtained. It is obtained by the division of the cell into two—which is reproduction by fission. Where the cells after such division remain attached to each other, so as to form a composite body, as in plants, the increase of the body is *growth*; but where cells, after division, separate from each other and each piece goes on growing up to the mature size of the parent cell, it is growth to be sure, but it is interrupted and disconnected growth, or, as it is usually expressed, *discontinuous* growth. But it is also reproduction, for it reproduces the parent cells and perpetuates the race. This form of reproduction is called asexual. The lower forms of vegetation reproduce asexually by detachable buds or bulbils, or by fission, as some algæ, the liverworts, many ferns, some grasses, &c. Animals which reproduce by budding, or gemmation, or by fission, are asexual. Most protozoa, such as the Gregarinæ, Monera, Amœbæ, some Sponges, &c., many Coelenterates, as hydra, corals, sea anemones, and some worms like certain Turbellarians and sea worms, liver flukes, tape worms, &c., reproduce asexually. The growing of the different parts of an animal or a vegetable consists of the division of the cells in the same manner as the asexual reproduction of the protozoa. The cells, when so produced, however,

remaining attached together to form a body or individual. If you take a piece of grape vine or slip of currant bush and bend it down and cover with a little earth, it will soon develope roots. Without disconnecting this slip from its parent root, by a strictly continuous growth, it has become a new bush or vine. But it may be cut off from its parent before developing new roots, and as a mere slip be sent by mail across the continent, and then when stuck into the ground will develop roots and grow as a new plant. Here the growth is discontinuous certainly, and it is reproduction, but it does not differ in any essential particular from continuous growth. You may cut a riding whip from a willow tree, and if, after accomplishing by its help a journey of forty miles, you stick it in a moist spot of earth, it will grow into a tree. But if you make the experiment with a peach, apple or oak switch it will not work. These switches will never produce roots. There has been a differentiation in these trees by which the common branch has lost the power of reproducing the roots, and this power has become invested in a certain concentrated part of arrested growth ; viz, the peach stone, apple seed or acorn. The limb or twig retains the power of the growth resulting from the divisions and multiplication of its own cells, and you may take the twig of the apple or the bud of the peach and stick it into another tree in such a way that it can get proper nourishment, and it will continue to reproduce its cells and grow. It is so of the higher animals also. There has been such a differentiation that, while all the parts continue to grow by the asexual reproductive process of the cells of their own tissues, the possibility of reproducing all the tissues in a complete animal is not retained in every cell, but is transferred to certain specialized reproductive cells. In a Star-fish (as in a Willow), one limb or ray detached will reproduce the other four and re-form the animal complete. In an Amphibian the differentiation has proceeded so far that the limb can no longer reproduce the rest of the animal, but the rest of the animal can reproduce it, so that a salamander may have a new tail or a frog a new leg. In the mammal the differentiation has become still more pronounced, so much so that it is rare that a lost limb grows on again. But the power of asexuai cell reproduction is still retained by all the separate tissues. If it were not so there could be no growth except of excretory matter. This power enables the tissues to repair themselves (within certain limits) like a broken crystal. A finger nail torn off, or hair plucked out, or a bit of skin stript off will be replaced ; a muscle, nerve, blood-vessel, or bone disrupted will be knit together again. Thus, as we advance up the scale of organization, we find the differentiation of the tissues to become so pronounced that the cells of one tissue, while they reproduce their own kind, cannot reproduce those of another tissue, and the highly organized body may be likened remotely to a conglom-

erate rock composed of a number of different sorts of crystals, each independent of the rest and yet necessary to the integrity of the whole. The wider the tissues are differentiated from each other, the further are their constituent cells from the condition of those original cells of universal function with which the power of the reproduction of all the tissues always remains; and the narrower the limits within which the tissue cells may vary from their normal quality. This being so, I think it necessarily follows that the functions remaining in the reproductive cells are likewise intensified, and that therefore the higher organisms breed truer than the lower ones, an inference which I believe observation amply bears out. The reproductive cells themselves, like the cells which form the tissues, are subject to growth and division, which in their case, considered as cells simply, constitutes their asexual reproduction.

Asexual reproduction, which is the rule for the growth, continuous or discontinuous of the simplest animals, and of the simple tissues of the complex animals and plants, is superseded for the reproduction of the body in all the more highly differentiated organisms by sexual reproduction. Sexuality is a condition of things in which the cells differentiated to reproduction have undergone a further differentiation, so that one-half of them have lost *one part* of the reproductive function which has been assumed by the other half, in doing which this latter half has lost *another part* of the reproductive function, which has in like manner been assumed by the first half; so that the general reproduction of the organism cannot proceed till two cells having these complemental fractions of function be got together. This differentiation has been a gradual process, and we find it in various degrees of emphasis and completeness. In those asexual animals which are only so far differentiated as to have the reproductive cells distinct from those producing tissues, the reproductive cells are usually to be found together in one place and developing in connection with a special gland. And when sex differentiation begins, both kinds of sex cells are at first found developing in the same gland. Then the two kinds are developed alternately; then one kind at one period in the life of the individual, and the other kind at another time from the same gland. Then there are two glands, one for the development and keeping of the female cells, or ova, and the other for the male cells, or spermatozoa. Both these glands are at first in one individual and near together; later they become separated in different parts of the same animal; and finally the female cells are found in one individual and the male cells in another. When both kinds are found in a single individual, it is called an *hermaphrodite*; when an individual has but one kind it is *unisexual*. Amongst both plants and animals are to be found these three conditions as regards reproduction; viz., asexual reproduction, hermaphroditism, unisexuality. Most plants

that we ordinarily meet with are hermaphrodites, but a considerable number are unisexual, one plant bearing the fertilizing pollen, and another, the ovules, which when fertilized grow into the seed. The lowest plants are asexual like most of the lowest animals. The following comprise most of the hermaphrodite animals, those of a lower grade than these being asexual, and those of higher organization unisexual:

Some *Sponges* are Hermaphrodite, others unisexual. "But among the latter it is not uncommon to find (e. g., in *Sycandra raphanus*) that the production of one set of elements preponderates over the other, and thus we have hermaphrodites with a distinctly male or female bias. In other words, they are verging towards unisexuality."[1]

Cœlenterates.—The members of this class are higher in having the production of the sex cells more restricted to definite regions, tissues, organs, or even persons. "The highly active Ctenophores, like *Beröe*, are all hermaphrodite, and that very closely. On one side of the meridional branches of the alimentary canal ova arise, on the other side, spermatozoa." Some sea-anemones and corals are hermaphrodite. In the case of *Corallium* (the red coral) "the whole colony may be unisexual, or one branch of the colony, or only certain individuals on a branch, while genuine hermaphroditism of individual polyps also occurs. Among hydrozoa (zoophytes, swimming-bells, jelly-fish) hermaphroditism is a rare exception, or we may almost say reversion. The common hydra, which is a somewhat degenerate type, is hermaphrodite, though at the same time individuals may be found with only ovary or only testes."

Worms.—Among these, the turbellarians are all hermaphrodite except two genera; the trematodes or flukes are likewise hermaphrodite, except one or two genera; the cestodes, or tape-worms, are all hermaphrodite. These are parasites. Most nemerteans are unisexual, but some are hermaphrodite; all leeches are hermaphrodite; the thread-worms, or nematodes, are all hermaphrodite except one genus *Angiostomum*. This animal has a reproductive gland which first produces spermatozoa and afterwards ova, which are fertilized by them. Of the higher annelid worms the *Protodrilus* is hermaphrodite and so are the earth-worms, but the marine-worms are unisexual except one genus, the Sagitta. *Echinoderms* are all unisexual except one brittle star and one genus of sea-slugs (*Synapta*). *Arthropods.—Barnacles* are mostly hermaphrodite, but most crustaceans are unisexual. In the Cymothoidæ (Isopods) the sexual organ is male while the animal is young, but becomes female later in life. Myriopods are unisexual, and so are insects, with one exception. *Mollusks.*—Oysters, clams, cockles, &c., are hermaphrodite, but most other bivalves are unisexual. Of snails, or gasteropods, the *Streptoneura*, or twisted nerves, are of separate sex, but the straight-nerved *Euthyneura* are hermaphrodite. Pteropods are hermaphrodite; Scaphopods, or Elephant's-tooth shells, are unisexual, and so are the Cuttle fishes.

There are many casual instances of individual hermaphroditism amongst tribes usually unisexual. They are doubtless due to arrested development. They are occasional amongst birds and mammals, such conditions usually resulting in sterility. They appear to be tolerably common among the amphibians. "Thus Marshall notes that the testes of a common frog may be associated with genuine ova, or an ovary may occur on one side, and a testis with an anterior ovarian portion upon the other. Bourne gives the case of a frog with the ovary well developed on the right side, and opposite this an ovary anteriorly replaced by testis. One of the toads (*Pelobates fuscus*) seems to be frequently hermaphrodite, the male being furnished with a rudimentary ovary in front of the testis. A similar hermaphroditism is not at all infrequent in cod, herring, mackerel, and many other fishes; while slightly lower down in the series it occurs in the hag-fish (*Myxine*), sometimes a fish is male on one side, female on the other, or male anteriorly and female posteriorly." "Among invertebrates the same has been occasionally observed, especially among butterflies, where striking differences in the coloring of the wings on the two sides have, in some cases, been found to correspond to an internal coexistence of ovary and testis."[2] Lobsters have been found with similar internal arrangement, and something analogous has been observed in a Deer. Traces of hermaphroditism in man are shown in his rudiment called the male uterus, and in woman in the rudiment called the parovarium. (See fig. 30.)

Although hermaphrodites possess both the sexual elements in one

[1] "Evolution of Sex," Geddes and Thomson, 70.
[2] " " " " 66.

individual, it is said to be rare that self impregnation occurs. One sufficient reason of this is that usually the production of ova and of spermatozoa does not take place simultaneously. There has been such a differentiation of the sex elements that the same sort of "protoplasmic rythm," which developes one kind will not develop the other; and as Geddes & Thomson say, "Antagonistic protoplasmic rythms may rapidly alternate, but cannot coexist." So that by reason of this alternation in the production of the sexual elements, they are not to be found ready for each other in the same individual; but in a community, or tribe, it will always happen that the male elements produced in one individual, will be simultaneous with the female elements produced by another. The habitat of most hermaphrodite animals is the water, and the ova and spermatozoa thrown off into it are drifted about and find each other by accident, or the spermatozoa are thrown off by one and find their way to ova in or from the female glands of another. In the case of hermaphrodite plants the male pollen is carried about in the air, or by flying insects, and thus reaches the ovules in distant plants which may be ready for it. In cases where the male elements happen to be furnished by an exceptionally vigorous individual, and fall upon female elements of inferior vigor, or vice versa, the result must be organisms in which the equality of sex function is disturbed, some individuals being more male than female, and vice versa. This sort of differentiation carried to an extreme results in the complete establishment of unisexuality in which one individual is the exclusive possessor of the male organs and another the female. Embryology proves that this is the process that has taken place.

It may be asked why it is that when a cell has reached such a size that its cover or surface is in just the right proportion to allow the substance within to get its proper nourishment and respiration, and get rid of its waste matters and no more, such cell does not simply stop growing, and remain an adult indefinitely, instead of breaking up and starting over again? We can answer this question provided we can answer another, which should have the precedence; viz., why did the cell in the first place take up nourishment and grow at all? A speck of protoplasm, consisting of a chemical union of four elements, viz., oxygen, hydrogen, nitrogen and carbon, and held together by the polar forces of chemical affinity, is necessarily in contact with its environment—air, water, earth, light and heat. This direct contact subjecting the outside of the body to stimulations different from those assailing the inside, develop the coat or cover, and they develop in the body a shifting and movement of the particles composing it, that entails loss of some of the molecules. When such loss occurs the cell is said to be hungry, and if it is in contact with nutritive matter it absorbs some of it to re-

place that which is lost; that is, in the disruption of the lost molecules bonds have been broken which remain as attractive poles until satisfied or neutralized again by the attachment of new particles. The cell is subject to a normal growth, up to a certain limit, in addition to its repairing operations, which growth is likewise due to the impulse of polar forces. We must conceive the molecules of the cell to be possessed of unsatisfied bonds by which they attach the new molecules of nutrient matter to themselves. See the theory of chemical attraction.

As shown elsewhere, the activities of the forces of the environment of every body of matter are competent to develop in such body currents of electrical energy, and establish poles or centers of attraction and repulsion. Organic cells are not exempt from this law, and while every molecule has its independent current and its poles, the cell, as a whole, has its likewise. And so has the nucleus within the cell. Chemical affinity is regarded as the result of a polar energy. Hunger is the expression in consciousness of the unsatisfied affinities of the organic molecules composing our tissues. In the absorption of food by an organized cell, the cell may be regarded as positive and the food particles negative. As the cell grows in size by this absorption the poles recede to a greater distance from each other and each pole gathers about it the organic elements subject to its sphere of attraction. This is illustrated in figs. 126 and 127.

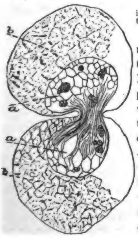


FIG. 126.

FIG. 126.—Division of *Animal Cell*, showing nucleus *a* in process of forming two daughter nuclei; and the protoplasmic network *b*. (G. and T. from *Carnoy*.)

This establishment of two poles and two nuclei with their mutual repulsion involves the mechanical division of the cell into two. It seems then that the very energy which compels the building of a cell insures its rupture when complete. This rupture is essential to the continuance of vitality. Death of an individual is therefore only an incident of life —of the general sum of organic vitality, of which each race in the first place, and each individual in the next, becomes a convenient vehicle, just as a stove is a convenient radiator of heat. But vitality is not an inherent quality of an organism any more than heat is an inherent quality of a stove. The phenomena, the sum of which we call vitality, are the effects upon the cell, or upon the body of cells, of the impact of external energies whose existence in no way depends upon the organism, but which, on the contrary, build up the body, keep it moving as long as it remains flexible and

mobile, and then tears it down and dissolves it. But usually, as a preliminary to the dissolution of the individual body and as more or less contributory to it, a portion of it containing the essential elements of the whole is transferred to a safe place where it is caused to grow to maturity and reproduce its parent, thus insuring the perpetuity of the

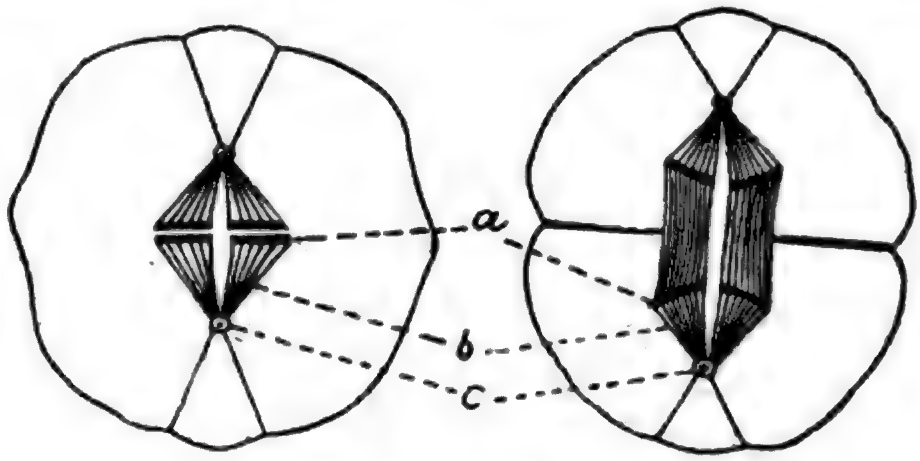


FIG. 127.

FIG. 127.—Diagram illustrating cell division. *a.—Chromatin*, or essential elements of nucleus united in the left fig. and drawn apart in the right, in the formation of the daughter nuclei. *c.*—The polar protoplasmic centers. *b.*—Protoplasmic threads or filaments, extending from *a* to *c*. (*G. & T. from Boveri.*)

race. If vitality were an inherent quality of the organism we should have a right to expect that the child would exactly resemble its parent. But from the fact that the energies which assail the child are not of precisely the same vibratory rates and force as those which governed the parent, the child differs from the parent; and this difference accumulating from generation to generation constitutes the evolution of new species and races. Obviously, then, the conditions which evolve a new race are unfavorable for the perpetuation of an old one; or, in other words, unfavorable for *its* perpetuation, and the process of changing individuals from generation to generation effects the change of race. And thus we see how the reproduction of new individuals involves the dissolution of old ones, and the evolution of new races involves the extinction of their predecessors. The answer, then, to the question why a cell does not remain stationary when maturity is reached, is that the energy which built it will not let it alone.

A great many skillful and patient observers have spent a great deal of time in watching the formation of the two kinds of sexual elements and their mode of union and development; and they have also observed the growth of the simple asexual organisms from the original asexual cells. These observers agree in the main as to the facts and processes, but have not succeeded in framing a satisfactory theory to account for them. Of the theories that have been framed no doubt several contain some elements of the truth; although it is not yet possible to work out any theory in great detail. Those who have attributed the phenomena to the activity of *polar energy* are certainly on the right track. Not that there is an innate tendency in "vitalized matter" to "unfold," or

anything of that sort, but that an adequate force of such current electricity as operates to form crystals also operates to build a cell in a suitable solution. All that appears to be necessary to start the construction of such a cell is a "germ" to serve as a nucleus, or a place of beginning, and a certain degree of heat. The heat is a mode of energy, and, when of a certain degree of intensity, under the conditions named, part of it takes the form of current motion. While it remains heat, it is demonstrated to be the vibratory motion of an unseen material substance, to which the name of *ether* has been given. When it becomes current, it is reasonably certain that this same ether is moving bodily. The currents may be gentle and slow or they may be powerful and rapid. In all the operations of cell building, involving growth and vitality, they are gentle and slow. The shape of a germ or nucleus without doubt determines the direction which the currents shall take in passing through it, and the position of the *poles*. And the poles may be defined as the points of intersection of a large number of *lines of force*. (See chapter 36.)

The currents of ethereal energy are competent to carry with them certain particles of the plastic matter through which they run, and to disturb and rearrange the rest. This rearrangement, by altering the shape of the organized mass, also changes its polar centers, and gives new direction to the lines of force, and new places of deposit for such portable particles as may still be subject to their carrying power. In the construction of a cell in a plastic mass of appropriate matter, therefore, we find currents carrying materials to the germ, reinforcing and building it up and continuing through it, arranging them in a definite and orderly manner. (The subsequent split calls to mind the action of the diastase in splitting the sugar into bodies which twist light, one to the right and the other to the left, and which, by repelling each other, show that they are differently affected by magnetic currents.) These currents do not originate themselves or spring from nothing, but are "generated" by the action of some other mode of energy, as heat, or friction, or chemical action, &c., and are developed in connection with some ponderable body, as, for example, the organic molecules and cells under consideration. Electrical or magnetic energy, instead of being current may be restrained in consequence of a lack of a proper conducting medium, and so be in a state of compression, or tension, as it is called. The points at which such tension occurs are called poles, one being positive and its opposite negative. Two bodies, in both of which the tension is alike, that is, either both positive or both negative, repel each other; but if the tension is positive in one and negative in the other, they attract. So, two currents flowing near each other and parallel and in the same direction, attract each other, but if they are moving in contrary direc-

tions they repel; and this applies whether the currents are straight or in circles or coils. The manner in which currents influence bodies is not the same for all. A current may form a magnet which will attract certain bodies and repel others. The same magnet which attracts iron, nickel, cobalt, manganese, oxygen, &c., will repel antimony, bismuth, phosphorus, sulphur, sodium, nitrogen, carbonic dioxide, water, starch, sugar, bread, apple, blood, beef, alcohol, and many others. In addition to the recognized electrical or magnetic action there is chemical attraction, which is regarded by many chemists as a form of polar force akin to, if not identical with, magnetism.

We see in these various phases of polar energy the ability to communicate to the materials which are made to enter into the composition of the cells, all the movements they make, both before and after their organization. We see the cells constructed by the aggregation of particles from without, until a certain size is reached; presumably a size which, under the conditions, no longer admits of the proper access of oxygen to the central part of the cell. Thereupon, from some cause or other, repulsion arises between the two halves of the nucleus, which also involves the rest of the cell and ends by splitting it in two. The decisiveness and finality of this separation vary greatly in the cases of different classes of cells. In some, the pieces instantly become reattached and remain together to form a continuous body of skin, muscle or other tissue, or they may remain separate and form the whole of a simple, single-celled organism, like a diatom; or the pieces resulting from the split may be incompetent to reunite with each other and so drift about till they come within the sphere of attraction of a foreign cell with which they can unite. These last represent the sexual cells. The first class named are usually alike in size and appearance, and the energy which operates upon them first augments, then splits, then reunites the pieces, and then—repeats the operation. In the second case, that of the diatom, there appear to be but two stages; the energy augments, then splits, then repeats. These are two varieties of *asexual* reproduction, and the cells created by both varieties are *alike* in size, and the first sort are alike in polarity and joined by mutual attraction or united by a bond of connective protoplasm. The compound body thus formed may be the whole of a small organism or only one definite part of a large one. The young diatoms are likewise alike, but they may be supposed to be of a neutral or sluggish magnetic constitution; that is without affinity for each other.

The sexual cells, in their most elementary form, must be alike, as two diatoms, yet with an attraction for each other more intimate than that mentioned above, as uniting the cells of a tissue; for their union becomes so intimate as to form a single cell out of two, before any

division takes place. According to Hæckel the Protomyxa, one of the slime moulds (*myxomycetes*) passes through three or four stages of development. First, it is seen as a mass of slimy protoplasm; then it be-

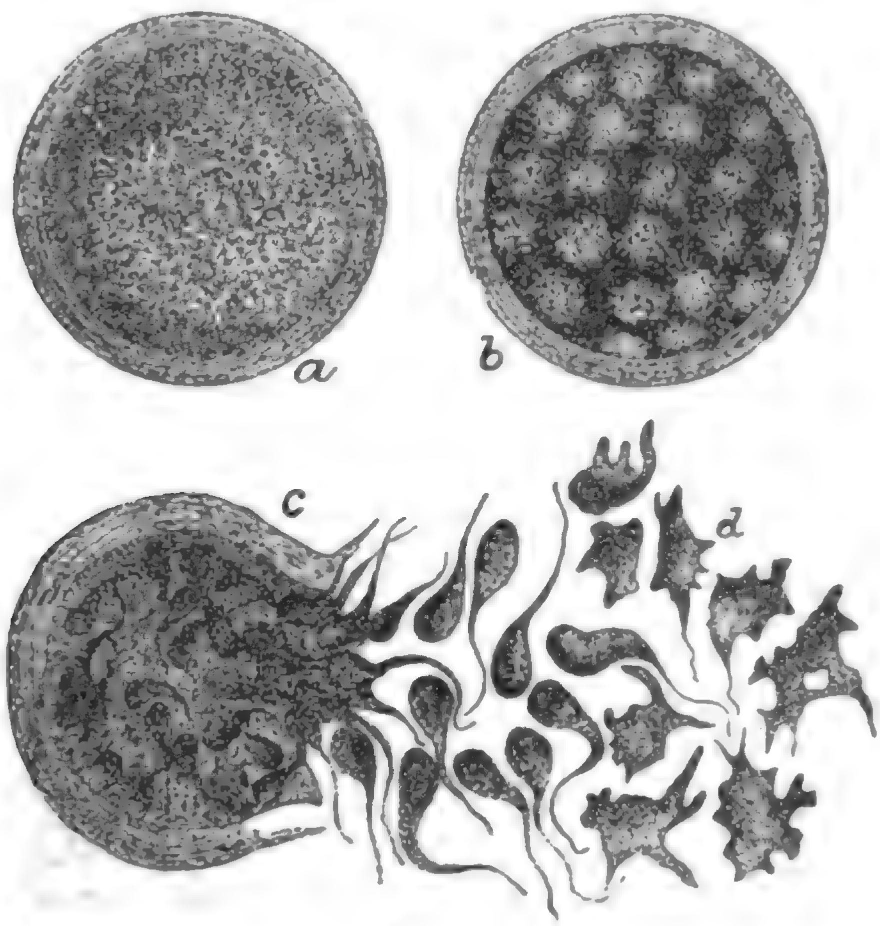


FIG. 128.

FIG. 128.—Metamorphoses of the slime mould *Protomyxa*. (*After Hæckel.*)
a.—Protomyxa encysted.
b.—Division of the protoplasm into individuals within the cyst.
c.—Bursting of the cyst and liberation of the tailed spores.
d.—Transformation of the spores into amœbæ, which unite to form the *plasmodium*.

comes a little ball enclosed in a bladder or cyst, and it is then said to be encysted. The protoplasm inside the cyst becomes separated into a number of nuclei, each of which develops into active spores with tails. When this development is complete the wall of the cyst becomes ruptured and the spores escape. In a short time these tailed spores become so many amœbæ; and finally a lot of these amœbæ join together to form a slimy amœboid mass called a *plasmodium*. The fusion of these protoplastic units in the formation of this new body illustrates the union of the sexual elements, if it is not itself a primitive example of such union. These units, before the bursting of the cyst, appear to be under an influence that causes them to repel each other. After their liberation they are subjected to an opposite influence and they attract. Such attraction continues to draw these elements together until a new cyst is formed, when the force is reversed and the operation is repeated. The essential elements of sex, then, taking this case as an illustration, consist of two cells of equivalent value, which are first consolidated by the predominant energy of their environment into a new body, which then falls under influences that cause its segmentation into cells in the

formation of germ layers and the construction of a body. In a hermaphrodite worm the development of both the male and female glands may be traced from a single cell. This cell splits into two, each of which, by growth and segmentation, becomes a sexual gland—one male and one female. When the animal reaches maturity these glands bear fruit in the shape of sexual cells, and the reproduction of the animal follows the union of a cell from one gland with a cell from the other. In the development of the animal, as soon as the segmentation of the egg and its division into cells has begun, one cell becomes set off to itself to form the new sexual glands, while all the rest go on undergoing segmentation and growth into the other parts of the body. If we compare this process of reproduction with that of the mould Protomyxa, we see that the part concerned especially in reproduction, imitates the round taken by the mould. The *ovum* of the worm answers to the *cyst* of the mould. In the ovum, as in the cyst, the contents divide up into subordinate organisms. In both cases they become liberated. But here a *partial* differentiation comes into view. Only two cells, arising from the organization of the protoplasm of the ovum, persist in making the grand circuit, while all the rest become enlisted in the formation of the organs which go to make up the body of the animal, and so have no further *direct* concern in reproduction. But these two exceptional cells do essentially as the liberated tailed spores of the mould do, that is, they form a *plasmodium*, or its equivalent, and this becomes encysted in the form of the impregnated ovum (cytula), and the circle is complete. There is, however, always more ceremony, preparation and delay in the processes of sexual reproduction than the above comparison would seem to imply, and the higher the animal the greater the complexity. Thus it is only in a few simple animals that this special very early separation of the cells devoted to reproduction from the rest, has been actually observed. According to Geddes and Thomson, the fly, *Chironomus*, is the best example, while it has also been observed in other insects; in the worm Sagitta, in leeches, in nematode or thread worms, in some crustaceans, in the water-flea Moina, in some spiders, and in other animals. In all cases there is a pause in the development of these separated cells; that is, they do not immediately proceed with the function of reproduction, but appear to wait for the body cells to gain a degree of development first. These last appear to monopolize the plastic material in their own development until they approach a certain degree of completion, when there is a let up in their demand and the material and energy go toward the support of reproduction. The duration of the interval between the segmentation of a cytula and the formation of a daughter ovum varies greatly in different animals. Among mammals it ranges from about two months to twelve years or more, depending on

the size and workmanship of the body. Among some of the protozoa, the interval is nil where there is no body, and it runs up to days or weeks or longer where there is one. But all this time, long or short, is not lost. While the greatest activity appears to pertain to the development of the body, there is yet a very important sub-activity in connection with the reproductive elements. The body itself (of the next generation) is to be reproduced, and, therefore, since it cannot reproduce itself it must be done in connection with the separated sexual elements. That is, the sexual elements constitute a nucleus—the nucleus of a crystal, let us say—around which the modifying influences of the body are thrown. So, while the sexual elements possess their hereditary bent or crystalline constitution, it is but little if any more than a protozoan constitution, until they receive the reinforcement of body elements and the directive influence of body currents which cannot, of course, happen until there is a body. So we may suppose the interval of time under consideration, is employed in reinforcing the semi-protozoan hereditary sexual elements, with the piggish, doggish, cattish or mannish elements of the body, as they are severally growing into their own definite characters. This modification of the hereditary stock, by the body, continues as long as it lives in such body. When the germ is turned out from an old body to become the basis of a new one, the modifying elements it received in the old, unfold in the formation of the tissues of the new.

In connection with the hereditary sexual elements organs called glands are always formed; viz., testes and ovaries.

These organs appear, in the lowest sexual animals, to be formed by the sexual cells themselves, and when reproduction is to be accomplished, one cell detached from one such organ is a spermatozoon, and one detached from another one is an ovum. While, as mentioned above, among many simple animals the sexual elements are directly hereditary by means of cells, one generation of cells begetting another, indefinitely, this has not been observed to be a universal rule. Some biologists think that although not actually seen and traced it must, nevertheless, be the rule in all cases. Others hold that the continuity of the sexual elements is through a perpetuation of a *germ-plasma*. In all probability both parties are right. If we go back to our Protomyxa again for illustration, we observe that part of the time it is a cyst or cell, and part of the time it is in the shape of a "plasmodium," which is entirely comparable with a "germ-plasma." There is no violence to known facts in the hypothesis that during the preparatory interval discussed above, the sexual elements are in many cases in the condition of a germ-plasma, and a part of this material is used to construct the sexual gland. When maturity is reached the unused part of this plasma serves as a guiding agency in the molecular arrangement of the elements of new germ-plasm secreted

through the reactions of the sexual gland, by which agency it is drawn about nuclei and aggregated into functional cells. These nuclei, both in the case of the male and the female elements, assimilate nutriment, increase in size, and then divide, as is the usual mode of increase among elementary organisms, not always equally, however, nor completely, nor after the same fashion.

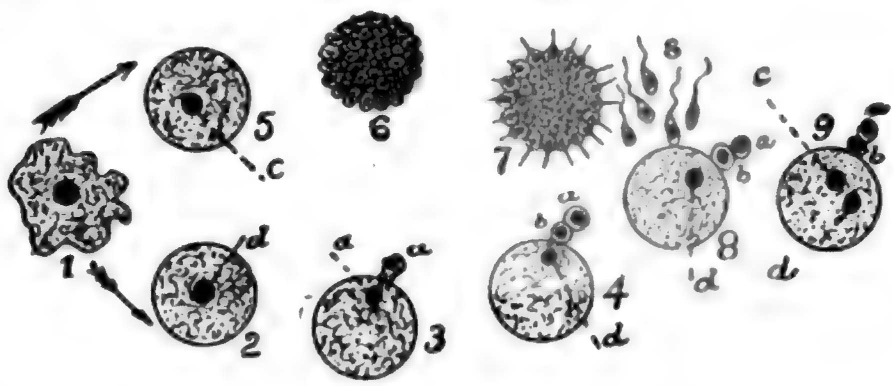


FIG. 129.

FIG. 129.—*Diagram* of *Development* of *Reproductive Elements.*

1.—An Amoeboid Sex-cell which may give rise to either or both male and female cells.
2.—Ovum with nucleus (*d*).
3.—Ovum extruding first Polar body (*a*).
4.—Ovum extruding second Polar body (*b*).
5, 6, 7.—Sperm Cell undergoing segmentation into spores.
s.—Mature Spermatozoa approaching Ovum (8).
9.—Male and Female nuclei *c. d.* approaching each other.

(*Geddes & Thomson.*)

Division is especially conspicuous with the male elements, spermatozoa. But the behavior of the female elements, the ova, is in some cases peculiar. Instead of the entire egg splitting into two equal halves, the nucleus only divides equally, but one-half retains the whole or nearly the whole of the substance of the egg, while the other half, with a very small accompaniment of protoplasm around it, separates, or is "extruded" from the more bulky part. This process is called the "extrusion of the polar globule." "Polar globule" is correct, but we are not to suppose that this one is any more polar than the half nucleus left behind. Soon after this first extrusion, in most cases, a second one occurs, the nucleus in the ovum dividing again and sending off polar body No. 2. These divisions reduce the nucleus of the ovum to one-fourth its original size. These extruded nuclei frequently hang around the outskirts of the ovum, and it sometimes happens that they divide, and occassionally they are joined by a spermatozoon in a union which of course does not result in any further growth. It is evident that this division of the ovum is the equivalent of the usual division of elementary cells, and that the extruded globules are as female as the nucleus which remains in the body of the ovum and differ from it only in their poverty of equipment in the way of nutritive protoplasm. The difference in general between the male and female germ cell appears to be that the former is *holoblastic*, or nearly so, while the latter is *meroblastic*. (See page 29.) The male cell undergoes segmentation until it is all turned into spermatozoa, each with a small bit of accompanying protoplasm,

while the female cell seems to form but three nuclei, the greater part of the cell not undergoing segmentation at all, but remaining with one of the nuclei, the other two being "extruded." Thus the male elements are far more numerous and in the same proportion far less certain of becoming functional than the female. The case appears to be very similar to that of the sexual plants, the pollen or male element of which consists of a great multitude of granules which must be transported a greater or less distance through the air with the certainty that a vast majority will be lost; and the ovules of which answering to the animal ova, are comparatively few in number, sedentary, secure and surrounded by stores of nourishment. In their original essential qualities there is no reasion to doubt that the sexual elements are exactly equal in all respects, except that their polarities are complemental, causing them to attract each other when they come within a certain distance. After the division of labor took place, which assigned to one individual the male and to another the female elements, the necessary difference of habit imposed upon the two would inevitably lead to a differentiation in the relative number of the two kinds of elements and the conditions surrounding them. For illustration, suppose the first sexual colony to be composed of males and females practically equal in numbers, and producing spermatozoa and ova equal in number, activity, and capital, in the way of protoplasm accompanying the nucleus. They are water animals and cast off these elements to find each other by accident, under conditions that insure disappointment to the great majority. No equality of any sort remains constant unless the conditions producing it remain the same, and they never do. If the first generation in our colony are equal, the second will not be, for some will have been better fed, and have had better general opportunities than others. The reproductive elements of these superior individuals will be more numerous, more active and better provided for. A larger proportional number of the spermatozoa of such individuals will find ova and so tend to increase the number of males producing *numerous* and *active* spermatozoa. The individuals among *these* most likely to have a history are the most active ones; and these are the ones least encumbered with an excessive amount of protoplasm, or whose protoplasm becomes active, as in the case of cilia or flagella. The tendency then would be to develop males with power to produce a great number of spermatozoa, lightly equipped with active protoplasm. But since the spermatozoa have become mobilized by casting off their impedimenta, it is obvious that to make things even they must reach ova that are well provided, and the most successful matches would therefore be between the most active and lean spermatozoa and the best dowered and therefore the least active ova. It might be said that under the conditions of the hypothesis the ova should

become lean, active and numerous as well as the other sex. If they did they would have to mate with the slow and fat ones of that sex, and in that case the lines between the sexes would have to be rearranged, because all the subsequently developed characters of femaleness, necessarily follow the fat element, and if there is no antecedent force to differentiate sexual distinctions, this alone would do it. But sex precedes and consequently determines which shall be the more *active* party. At the time of the first separation of a single cell into two halves, each of which (as in the case of the *Sagitta,*) may become the foundation of a sexual gland, one male and the other female, we are to understand that there has been a polar repulsion between the two pieces, just as if two magnets had by some force external to themselves been turned so as to present their positive poles towards each other. It is at this point that the separation of the sexes takes place, and there is no doubt that the process is gone through with in every sexual animal including man. In every one, male or female, the asexual reproductive element, at an early period of development, is split, and one half forms the beginning of testes, and the other half the beginning of ovaries. (As shown in chap. 3, however, the development of the former is subsequently suppressed in the female, and the latter in the male. See page 24.)

The separation of the asexual cell into the two equal halves, then, is the beginning of sex differentiation. And here we meet with an apparent paradox, because although we are constrained to affirm that these moieties are equal, we yet find that they begin very soon to behave in a different manner. But, again, remember the dextrose and levulose which are chemically *just alike* but which are exactly *opposite* each other in their reaction on a beam of light, one twisting it 81° to the right and the other 81° to the left. (See chap. 27.) They are constructed like two spiral stair-cases, one of which turns to the right and the other to the left. So we can conceive of the primary sexual halves of an asexual cell as being equal and yet reacting differently from the same stimulation. If a wire circuit carrying a current of electricity be cut in two, each of the severed ends will have a tension, one positive and the other negative. In electrical engraving, explained in chap. 36, it is possible to use either of these loose ends, but the *negative* end is better than the positive. The negative current seems to be the more concentrated and intense of the two, as if it were *narrow* while the other is *wide*. They are both of equal speed and quantity, and are therefore regarded theoretically as equal. When two polar bodies draw near to each other under the influence of attraction, it is because one is positive and the other negative, that is, one is pushed along on a positive and the other on a negative current. Now if in the case of our primary sex cells the negative current is in any degree more intense than the other, the negative

cell will be driven with more impetuosity than the other and will therefore appear the more active of the two. In the mild currents and tensions which rule in vital activities, the difference between the two is small, but no doubt is real and persistent, and therefore efficient and certain. Thus we first trace all the secondary characteristic differentiations of sex back to the difference in activity of the primary elements, the first sexual cells. And next, with reasonable certainty, we discover this difference in activity to be based on a fundamental difference in the motions of ether the most elementary form of matter.

Reproduction is a species of growth. There are different directions in which an individual may grow, depending upon the part of him toward which the stream of nutritive fluid is directed, a matter which depends upon the habit of his activities. If his brain, his muscles and his viscera each receive their due share, they will in time reach an approximate limit of growth and receive a check, in which case a portion of the nourishment is diverted toward reproduction, or the setting up of a new individual. A circumstance which diverts nourishment from the general body of the organism will tend to concentrate it upon the reproductive organs. What is remarkable is that when the total amount of the nourishment is great it is monopolized by the general body or the most active part of it, but if the total amount is suddenly reduced, an adequate portion, or at least a greater proportion, is diverted to the reproductive function; as if nature were satisfied to allow the present generation to live as long as there is plenty of food, but the moment the supply is short it must go towards the perpetuation of the race. In the spring of 1887, a certain crab-apple tree blossomed out to a degree I never saw equalled by any other tree, but in a few months all the tree, except the roots, was dead. The ground on which it stood had got too dry to support it, and its dying effort went toward reproduction. Pruning the roots of apple trees has a tendency to increase their fertility and the yield of fruit. So far as vitality and organization are transferred from a parent to a child, it is death to the former. The protozoa are indeed in one sense immortal. Apparently there can be no dissolution of a one-celled organism. Where there is a body which is composed of single cells, the dissolution of the bonds uniting these cells constitutes the death of that body even if the cells themselves should live on separately. The protozoon *Magosphæra* is formed by cell division into a many-celled body, which is no sooner complete than it breaks up, the cells composing it each setting up for itself to repeat the operation. But there are many such simple organisms, both animal and vegetable, which, in maturing and liberating the elements which form the next generation, end their own existence. Not merely the incipient multicellular organisms, like the Magosphæra, lose their own identity in

reproducing the next generation, but that is the rule in some species of the annelid Polygordius, in which "the mature females break up and die in liberating their ova. This is approached but suggestively avoided in a genus of capitellid sea-worms (*Clitomastus*). The whole organism is not sacrificed, but only an abdominal portion of the body. This is, in fact, one of the key-notes to reproductive differentiation—the sacrifice is lessened and the fatality warded off." (G. & T.)

But, again, we find in some thread-worms, or nematodes, (e. g., *Ascaris dactyluris*) that the young live at the expense of the mother until she is reduced to a mere husk. Similar sacrifice is noted in the case of many other of these simple organisms. There are many insects—locusts, butterflies, ephemerids, &c., which die a few hours after the production of the ova, the exhaustion of the reproduction being fatal to both female and *male*. In all such cases the differentiation of the reproductive cells from those of the rest of the body, or rather the differentiation of the rest of the body from *them*, has not proceeded so far

FIG. 130.—*Diagram* showing the relation between Reproductive Cells and the Body. The continuous chain of dotted cells, at the bottom, represents a succession of Protozoa; further on it represents the *ova*, from which the bodies, in more advanced life, are produced; the undotted cells and the projections to the right being the bodies. At each generation a spermatozoon fertilizes the liberated ovum. (*After Geddes & Thomson.*)

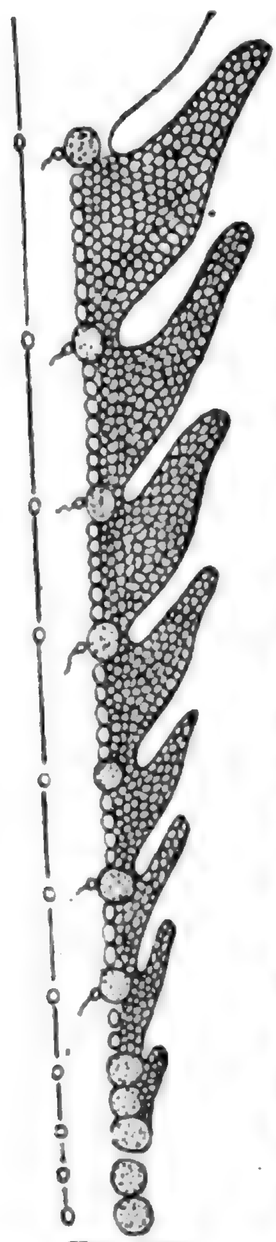


FIG. 130.

that the body can live without them. The nearer the organism is to the protozoa the less important the body outside of the reproductive department is. See fig. 130. In the single-celled protozoa it is nil, for the single cell is body and reproductive organs all in one, or rather the reproductive cell is all there is of it, and there is no body. Its disruption upon maturity ends with two live cells in place of the previous one, and no dead body, on which account it is said the protozoa are immortal. It may be said with equal truth that the reproductive portion of all organisms is immortal. This is illustrated by fig. 130, which shows the continuous life of the line of reproductive cells, and from this, as a single stem is set off at each generation, the general mass of the body, which, after surviving its term of life, suffers dissolution. It is true that the body exercises a reciprocal formative influence upon the cells of reproduction, and to that extent shares in their immortality, but the substance of the latter without loss is incorporated in the new generation.

It appears that between the multiple union of the amœboid individuals, which results in the formation of a "plasmodium," as in Protomyxa, and the dual union or sexual union of two

cells, there are intermediate sorts of union in which a number of cells, more than two, enter into combination before division—either fission or segmentation—can take place. First, in asexual organisms where usually growth by the absorption of nutritive matter proceeds till a certain point is reached, when the body splits in two, it sometimes happens that the preliminary growth is attained by several cells eating each other, or clubbing together and fusing their protoplasm. Some Algæ and several forms of simple animals have been observed to do this. Many of the simple Algæ produce spores by a preliminary union of the protoplasm of two individuals which appear to be attracted to each other, and to come into close contact; after which the cell walls between the two are obliterated and the contents of the cells fuse together. After a time this mixed protoplasm granulates into spores, and the cell bursts and sets them free. This is, to all intents and purposes, sexual reproduction. That is, the two protoplasms are of complemental polarity, and so they attract. In the cases in which three or four spores get together before they have sufficient capital to divide, the presumption is that some of them are neutral or indifferent—in some way are of incomplete or defective organization. They recall the indifference of the spores of Protomyxa when first discharged from the cyst, which soon after turns to attraction. There is certainly no difference in principle in the conjugation of cells, be they many or few. But great differentiations arise in the machinery of this conjugation, and in the morphology of the cells directly concerned in it. The earliest conjugations are between cells of similar form and appearance, while those concerned in the reproduction of higher organisms are more or less dissimilar in form and size, and between the two extremes there is a regular gradation without any sudden break. In Algæ the series of gradations is stated by Sachs to be complete "between the conjugation of similar cells and the fertilization of oospores by antherozoids."

In animals as well as vegetables the difference between the forms of the sexual organs and the immediate cells themselves has become pronounced. The difference in appearance, size and behavior between the spermatozoon and ovum has been sufficiently described above, and it has been sufficiently shown to be in the nature of the differentiation of accessory qualities and facilities, the essential qualities of sex not being subjected to differentiation by anything that could happen to it on earth, since it is founded in the ultimate motions of matter. Geddes and Thomson adopting Rolf's views have seized upon these secondary characteristics, and appear to regard them as essential. Thus the female cell, ovum, is characterized as well nourished, satisfied and quiescent; and the female is said to be correspondingly in a flourishing condition physically. The male cell is on the other hand said to be starved,

hungry, eager and active, and the male animal correspondingly restless, unsatisfied, enterprising. They attribute an average longer life to the female and cite cases of her greater size and power. They use the term *Anabolism* to express these alleged general characteristics of the female and the ovum, and *Katabolism*, to signify the downward tendency of the male and the spermatozoon. They generalize from the numerous facts they cite, that the essential condition of femaleness is anabolic and of maleness katabolic, and that these distinctions constitute the principal or only difference between them. I think this generalization is entirely too sweeping and is not in reality true of the original essential qualities of sex differentiation, but only of the subsequent incidents and accidents attending it, and not nearly all of those.

It is true that the ovum or female cell in the higher organisms is composed of a nucleus surrounded by a comparatively large amount of nutritive protoplasm. It is more passive and quiescent than the spermatozoon or male cell. The latter is likewise possessed of a nucleus, but the accompanying protoplasm is in small quantity, and part of it is in form of a flagellum or tail, by which the cell is locomotive. Both the male and female cells are chemically organized polar bodies with unsaturated affinities, and whenever they are brought within the influence of each other, these unsaturated affinities draw them together; but since by their physical construction the male cell is more mobile than the female, the former in many cases moves over the greater part of the space between them, and since the female nucleus is well within its surrounding mass of protoplasm, the male nucleus can reach it only by penetrating this mass. The wiggling of a tail in even a spermatozoon like muscular exertion in an adult animal causes waste of tissue which is followed by hunger or an unsatisfied chemism of the molecules of the tissue. This hunger may be satisfied by the introduction of the spermatozoon to any highly nutritive fluid for which it appears to have a powerful attraction.[1] But this hunger is not to be confounded with that other unsaturated affinity which causes the spermatozoon bodily to fuse its nucleus with that of the ovum, any more than the appetite which causes an adult male animal to seek the female is to be regarded as the same as that which causes him to seek his dinner. They are of a similar genus, but not the same species. So then we are not to regard the activity of the male cell in reaching the ovum as dictated by famine of the nutritive elements and a hunger to recruit lost tissue. The hunger for each other is mutual; the ovum surrounded as its nucleus is by a store of nutritive, protoplasm is nevertheless as eager for the union as the spermatozoon and though less active, is not passive. "It frequently rises to meet the sperm in a small attractive cone."

[1] See Geddes & Thomson, p. 125.

The *nuclear* elements of the male and female cells are undoubtedly complemental and equal in their essential functions as they are in apparent size. The difference of bulk between the two is in the protoplasm surrounding the nuclei. It is probable that the protoplasm of the male cell is more differentiated and more animal, while that of the female cell is less differentiated, more vegetative and more bulky. Why one cell should have remained passive, quiscent and bulky, while the other became active, mobile and unhampered, can be accounted for on principles of physiological economy. If both cells were passive they might never come within the sphere of each others influence or get together at all. If both were active they might fly around and still miss each other. The easiest person to find is one who is always in the same habitual place. But as I have shown above, the differentiation which creates sex in the first place, puts upon the male cell a little more activity of movement, which by differentiating its protoplasm would tend to increase its mobility. And this masculine activity would make unnecessary, and by so much discourage, activity on the part of the female cell, and so render it more quiescent and in better condition to conserve a store of provisions. But the passivity of the ovum is not to be unduly exaggerated. In the mammals at the proper moment it is liberated from the ovary and travels down the fallopian tube into the uterus, in which place, or on its way thither, it may be met by the spermatozoon which has traveled a somewhat greater distance to meet it. The union of these two into a single cell, and the subsequent segmentation of this cell, and the development of the embryo, are described in chap. 3, [Embryology]. The protoplasm accompanying the two cells is mingled to form a common supply for the immediate growth of the embryo. The mechanical advantage and necessity of the greater bulk of this raw material remaining with the more conservative ovum, and the more differentiated and mobile part with the more active spermatozoon, are obvious. As remarked above, the inequalities of sex, both in the primary sex cells and in the subsequent development of the individuals, have arisen from external causes and are not in the essence of sex. It has been shown elsewhere how parasitism tends to the reduction of the powers and activities of the individual. Among the true parasities the female is usually larger than the male. This difference is in the parts concerned in reproduction, especially the ovaries, ovisac, &c. The female being the nurse of the embryos, she becomes the receptacle and depository of the food; but as this food is absorbed from the host she lives upon, without effort to the parasite and is appropriated directly by the embryos, the agency of the female is purely passive and negative, and such "anabolism" as appears to accompany the process, belongs rather to the impregnated ova and the growing embryos than to the

female. If the sacrifice of the tissue undergone by the male in the production of spermatozoa is "katabolic," so it is in the corresponding process of the production of ova by the female.

The case is the same in the higher grades of life. Amongst the mammals the female is the nurse; and the *habit* of nursing has caused her to be supplied with a quantity of food for her *nursling*. That it is for her nursling and not herself is proved by the periodical turgescence, or menstrual hemorrhage which takes place, when in the absence of the nursling she gets rid of it. Then, again, the lacteal secretion, which Geddes and Thomson point out as an example of the anabolic habit, is absent, except when there is a progeny to profit by it. The extra supply of nourishment supplied to the female for nursing purposes, is drawn through her own food-elaborating economy which is compelled to do that much more work, and the process must, on the whole, so far as the mother is concerned, be katabolic. That this extra supply of nutritive matter to the female is a mere incident of her position and the duty put upon her of nursing the embryo and the young, is proved by the fact that it ceases at the termination of the child-bearing period, and by the fact that the milk-giving function is sometimes developed in the male, and in the case of man at least, might by habit become a common masculine function. Amongst the mammals and birds the males are usually the largest, strongest, and most vigorous, but this is due to habits of exertion put upon them by their social and domestic relationships and their position as head and defender of the family. The rule is proved by the occasional exceptions in which the female, by assuming similar relationship, has succeeded to the corresponding predominance in size and vigor. As masculine superiority, seen in birds and mammals, especially among polygamists, is no proof of a sexual anabolism on their part, so the superiority of females, where it occurs so commonly amongst invertebrates and more rarely amongst the vertebrates, is no proof of it on their part. The body is one thing and the essential qualities of sex quite another.

The essential difference between asexual and sexual reproduction is in the fact that when the asexual cell is divided the two parts are equal, and each half is an epitome, in reduced dimensions, of the original whole, and contains within itself all the conditions necessary to reproduce a copy of the parent cell; while the first differentiation which makes the two parts *unlike*, though still equal, necessitates that reunion or splicing which constitutes the essential feature of sexuality. The succeeding differentiations constantly exaggerate this first one, making the apparent distinctions between the moieties which stand in complemental relationship to each other more and more pronounced; constantly eliminating whatever elements of "maleness" may remain in the ovum, and of *femaleness* that may remain in the spermatozoon.

It was observed above that among the higher hermaphrodites self impregnation is not usual, and in many cases it is not possible, for reasons stated. Amongst the higher mammals, including man, breeding between individuals nearly related by blood, is often not possible, and when it does happen it is apt to result in a deformed progeny. Sexual unions of this sort constitute a return towards the conditions of hermaphroditism. True hermaphrodites, that is, individuals possessing both kinds of sexual glands in working order, are not met with amongst the higher mammals, or mankind, although partial hermaphrodites, or those having both sorts in various degrees of development short of functional perfection, are occasionally found, and are to be considered as cases of arrested development. But a male and a female *just alike* in *all* respects, except that one possesses the male and the other the female glands, considered together constitute the equivalent of a true hermaphrodite, because the latter is, to all intents and purposes, such a pair consolidated into one—or rather such a pair not yet separated into two. A pair nearly related by blood is apt to, more or less completely, fill these conditions; the reproductive elements of such a pair are not complemental and do not supply each other's deficiencies; what one lacks they both lack.

CHAPTER XXXIV.

HABIT.

If we now pause to take a brief retrospect of the ground thus far passed over we shall find *Habit* appearing as the immediate and visible cause of almost every organic change, whether in development or evolution. In the development of the embryo the successive changes follow each other in the order which the habits of myriads of generations have established. In the advance by way of these habitual changes the embryo is carried through numerous forms of no permanent use to it; forms which are maintained for only a brief space and then modified and altered out of recognition. No rational account of such an indirect and wasteful mode of developmental progress can be given, except that nature possessed no cheaper way, in general, than the way of habit. Wherever new habits have been introduced, such introduction has been effected by extremely slow processes, which have invariably consisted in the gradual modification of old habits—a modification so gradual, and taken on by steps so infinitessimal that every habit is, to a greater or less extent, always an old habit. What has been said on bilateralism, on the evolution of the osseous system, on the effects of food, periodicity, temperature, water and dessication, on respiration and parasitism,

shows how the slow modification of ancient habits have slowly modified the ancient organic forms. How different degrees and qualities of activity between the two sides of the body have conferred dexterity upon one side at expense of the other, how the periodicity of the molar movements of the universe have entailed a corresponding periodicity on organic habits, which has in turn been reflected on habitual organic forms, how varying habits of respiration have begotten varying forms of respiratory apparatus, and how, in the cases of animal and vegetable parasitism, the disuse of functions and habits is followed by the suppression of their characteristic organs.

It is to habit, therefore, the habit of function or movement that we must attribute the creation and modification of organs. This is conspicuously obvious from the numerous illustrations that have been given, and from the numerous other illustrations that cannot have failed to come under the observation of everyone. This induction implies that the function exists before the organ. It may be asked how a function can be performed before an organ for its performance has been created. The answer will be plain enough when we shall have considered the bottom facts and ultimate nature of differentiation and habit. As already often observed, the habit of the organism depends on the impulses of its environment. Some of our illustrations conspicuously point this out. Such is the case in "periodicity," in which the movements of the solar universe entail corresponding effects in the habits of all organic beings. The degree of saltness or freshness in water has its effect on the organisms within its influence. The force of currents of water and air has its effect in first causing new uses to be attached to old organs of locomotion, and, second, by this means of new habits, creating modifications of the organs. Endless argument might be brought to prove that the organism is made by its environment. To maintain otherwise is to hold that the organism is originally self existent, that something may spring from nothing, that the organic being may create something from nothing, and give more than it receives. This cannot be. Whatever force or energy an organism manifests, must have been loaned to it from a source outside of itself.

Fortunately, in the matter under consideration, the original cause of organic modification may be traced and located beyond the boundaries of the organic world—using the term organic in its accustomed sense, as distinguished from the mineral or inorganic. All the habits of organic bodies, whether vegetable or animal, are traceable directly or indirectly to habits of the motion and affections of matter, which, if not original and innate, were at least anterior to organisms. The constancy and persistency of these habits of motion are essential factors in organic evolution, for without such persistency the work of one age would

be destroyed in the next. But we have found that as a matter of fact the work of one age has served for a basis for the work of the succeeding ages, and that by reason of the general persistence of the forces at work, there has never been a cessation of life on earth since life first began. Such modifications as may have taken place in any of these conditions—as the geological or geographical—have been so slow as to enable the habits of organic life, as a whole, to become modified correspondingly, while as to that other series of essential factors comprehended under the phrase, *radiant energy of the sun*, they have remained practically constant and identical ever since life began on earth.

It appears, then, that *habit* depends upon force applied from without. In the case of lungs, for example, there are two bodies held apart, or at least parted, by force; viz., oxygen and carbon, the first outside of a skin, the second inside of it. Brought into each other's neighborhood, the carbon so comminuted by the digestive process as to be subject to the chemism of the oxygen, the latter penetrates the skin, separating the two and forms its union, and then as carbonic acid it passes back through the skin. This is the *habit* of respiration, and it specializes the part of the skin thus acted upon, into lung tissue. It is thus that habit differentiates, and that the function forms the organ, and the habit is that of the environment first, and after the differentiation the form of the part is such as to respond to the force that formed it, and to that force alone, or more readily to it than to any other. This facility of being acted upon by such energy or force indicates its differentiation, and the frequency and uniformity with which the action of the energy takes place constitutes its habit. The energies which act upon us and drive us to do whatever we do, are so familiar to us, and we have become so nicely adjusted to them through the habits of so many generations of ancestors, and respond to their influences with such facility, that we do not realize that our actions are so little our own. From what has already been said, we must begin to see that the forces of nature build up and tear down organisms, and that everything vital as well as everything inorganic constitute the mere playthings of these forces.

From what has been said in former chapters in regard to adaptation, it is obvious that it is not essentially progressive. The dynamic agencies by which the earth is surrounded, permeated and influenced, keep up a continual hubbub and movement amongst all its occupants. Races of organisms, like individuals, have their periods of infancy, growth, culmination, decline and extinction. After the culmination of a race its struggle for life is a losing game. In order to adapt it to changing conditions nature amends, reforms, adds to, subtracts from, patches and alters until there is no place left for a patch that will do any good, then she abandons it to its fate and turns her attention to a new one. Ex-

amples of this may be met with by the myriad. For a few favored races that appear to thrive and be in the ascendant, hundreds are reduced to the verge of a precarious existence. The tendency now appears to be to eliminate all animal races except our own.

CHAPTER XXXV.

ENERGY.

It is now necessary to make an incursion into the region of physics, in order to investigate the nature of the physical forces that assail the organism, impose its habits upon it, and set up in it the movements that produce the functions of sense and their accompanying differentiations. Bodies possess two obvious modes of motion. One is motion in the mass or molar motion, as, when a ball is thrown, it moves as a whole, while its particles or component molecules may retain their position with relation to each other. The other is molecular motion, or the movement of the particles or molecules with reference to each other, while the mass as such may be either in motion or at rest. Molar motion is frequently designated as "work" by physicists. The distinctions made between the different motions relate to the bodies moved and the manner in which they move. For example, the movement of a body from above toward the earth we call falling; a body going the other way is said to be rising. One movement of a horse's legs we call a trot, another a walk, another a kick. A bird flies, a fish swims. Such motions as these are in scientific parlance called *work*. When work is done it is simply an expression of some sort of energy that went before. Work does not do itself, or spring from no-work. The work of a steam engine is due immediately to *heat*; and heat has been proved to be a mode of motion of the molecules of bodies. The heat is created by burning wood or coal, which is chemical process, also molecular. So we see that work or molar motion may arise from molecular motion. In fact the motions are in reality only *one energy*, driving first the molecules of a body in an invisible manner, and then going over to another body and driving it in a visible manner; just as it is the energy of the same peck of oats that expresses itself in a trot one minute and a kick the next. The universe consists of *matter in motion*. As the matter appears to us in many subordinate forms, its apparent motions differ to correspond, the form of each determining the sort of motion it will take when driven. All the distinctive names that are given are simply for convenience, and not to be understood as describing different things, but only *one* thing under different aspects. That is, the same energy which is called *heat* in one body, because of the peculiar way in which it affects it, is called *work* when transferred

to another body because of another and a different way in which it affects *it*. As there are a great many different sorts of motions which are called work or molar motion, so there are many different sorts denominated molecular motion; such as *heat, light, chemism, electricity, magnetism, sound, gravitation.* Any one of these possesses the potentiality of becoming any other, directly or indirectly. That is, the same energy may appear in first one form and then another, till it makes the round and appears in all. Some of these terms express *phenomena* or the effect which the motions have on *us* and not conditions of the motions themselves, as will be seen further on. When energy appears by the motion of one body, we know that the same amount of energy has ceased to operate in some other body, or in some other form in the same body; and conversely when motion has ceased in one form we know that it has gone on in some other form, or *has done work* which when undone will yield again the same amount of energy. This is the principle called the *conservation of energy*, and it means that energy does not start up from no-energy and cannot end in no-energy. Accordingly then, molar and molecular motions are interchangeable with each other, and when one ceases, some form of the other must begin. When the motion of a falling body is arrested by the body striking the earth, the full energy of the stroke is instantly transferred to the molecules of the body itself and to the parts of the earth which were involved in the stroke, these molecules being set to vibrating with more or less violence according to the force of the blow; such vibration being called heat. Thus when a meteor falls through the air and strikes the earth it is always found to be hot. As long as it is above the atmosphere it is invisible because it is cold and solid mineral matter. As it passes through the air its motion is retarded by the resistance of the air; but this apparently lost motion is not lost; it is transferred to the particles of the air and the particles of the meteor so that the vibrations set up in it, which at first are heat, may become so rapid as to produce light. We can then trace the track of the meteor through the air. But when meteors do not become visible they nevertheless become hot in proportion to that amount of their speed which is arrested, and when they strike the ground and all the speed is stopped, the heat is increased still more. So the whole of a molar movement may be converted into heat. But on the other hand, while it is equally true that when molecular vibration is arrested it gives rise to molar motion (or work), yet as a common fact (in human experience and observation) the *whole* of the vibrations in any given case never *are* arrested. A part of them are, while the rest are communicated to other bodies and continue as molecular vibrations. Thus when heat is communicated to water, the expansion of the steam furnishes work, but much heat is necessarily

dissipated in the steam which is exhausted into the air after the work is done, in the hot water which never becomes steam, in the heated machinery, &c. And after a part of it does become work a considerable percentage is degraded back to heat by the friction of the machinery. The best engine utilizes only about $\frac{12}{100}$ of the heat in work, yet no part of the molecular energy is lost. It continues in some form, either molecular or molar, either heat, light, &c., or work. But an apparent exception to the foregoing is to be observed when work is done against the attraction of gravitation. If a bag of wheat be raised fifty feet to the top floor of a mill and left there at rest, there is an end of the work done to get it there and no increase of heat or other sort of motion to indicate what has become of the work. But if the bag should drop from the top floor to the bottom, the heat generated by the concussion, together with such other results as might happen in splitting the bag and scattering the grains, &c., would, in all, exactly equal the work done in getting it to the top in the first place. So that while it is above, it is said to occupy a *position* of energy. Its energy is *potential*, but not active. If it be dragged from one end of the upper floor to another, work is consumed in the operation and passes into heat in the contents of the bag and the molecules of the floor over which it passes, but the potential energy is neither increased nor diminished. Work done against chemical attraction as well as gravity ends in the same way by leaving the bodies separated by such work in a position of potential energy. The work done by sunlight in the leaves of plants is a compulsory separation of oxygen from carbon, the carbon taken from carbonic acid being packed away in the tissues of the plant, while the oxygen is dismissed into the atmosphere. Thus separated by force the two occupy a potential attitude toward each other. When the carbon in the shape of a stick of wood or a piece of coal is started to vibrate with enough rapidity to loosen the cohesion of the atoms, as may be done by friction or the application of fire, the reunion of the oxygen with the carbon takes place and the same amount of energy, in the shape of heat, is given off, that was required to disunite the two in the first place. Work done against cohesion, however, as when a log or a rock is split with a maul and wedge, is converted into the molecular energy of heat. It is parallel with the case of dragging the bag of wheat over the floor. The process does not alter the potential relations of the parts, but is only a method of degrading molar into molecular energy.

The two different modes of motion are thus found to be convertible into each other. But each of these two modes of motion, as before observed, is subdivisible into a number of varieties and phases. Everyone is familiar with the mechanical contrivances by which molar energy of one simple kind is caused to take on a great variety of motions.

The simple weight of water pressing vertically upon a turbine wheel hung in a vertical tunnel, causes the wheel with its shaft to revolve horizontally. Bevel gearing attached to the vertical shaft enables the motion to be transferred to a horizontal shaft, and a crank attached to this, gives vertical movement to a saw or a gang of saws. Other adjustments of gearing slowly push a log endwise against the saws, which, by tearing out particles of the timber against their cohesion, finally leave the log split up into boards. The molar motion of the water is thus transformed from a vertical rush to a horizontal whirl, in a part of the machinery, then to a vertical roll, then a vertical vibration, and is at last converted from molar movement to molecular motion, in the increased heat of the surrounding atmosphere, and in the machinery, the boards and the sawdust, and so disappears from observation. In this example we have several forms of motion, slow and fast, one part of the machinery going with lightning rapidity, other parts with deliberate slowness; some moving with a rotary vertical, others with a rotary horizontal motion; some with a right line horizontal movement, others with violent vertical vibrations. The machinery itself is of various materials arranged in a variety of forms. It is, in fact, obvious that the variety of forms the motion takes in passing from one part of the machinery to another is altogether due to these various forms, materials and arrangements of the machinery itself. If the journals were square instead of round the shafts would never revolve; if a single cog were missing from any of the cog gearing the saw would never go; if the saw were made of wood instead of steel, its work would very speedily terminate; if the lubricating oil were allowed to disappear from the bearings for a few hours, the energy arrested and converted into heat at the points of friction, would probably soon reduce the greater part of the mill to carbonic dioxide. The proper result is therefore obtained only by the operation of the energy upon a machine of particular form and adjustment. From the same shaft that runs the saw, a belt might be made to convey motive force to a printing press, a loom, a lathe, an electric dynamo, or any one of a thousand machines of a different form and accomplishing a different result. Starting with the water in a position of potential energy above the mill dam, we trace this energy converted into molar motion in the whirl of shafts and wheels to its final dissipation in molecular motion—*mostly* heat—mostly, but not wholly. In the case of the *dynamo*, if it is operated for illuminating, it ought to be mostly light; if the dynamo runs the street cars the energy becomes work again before it disappears as heat. Some of it reaches us in the shape of *sound*, in the hum, whirl and crash of the different parts of the machinery. If we should stand in glass slippers, or even rubber ones, near one of the rubber driving belts used in the mills for convey-

ing motion from one shaft to another, we should find ourselves becoming charged with electricity, and we could pass this electricity off in the shape of a spark from the end of a finger to another object. If that other object should happen to be the cheek or nose of a bystander, a further molecular effect would be observed in a slight sting in the receiving cheek and possibly in the delivering finger. Thus we trace the energy of the falling water through various forms of motion, which forms depend on the forms and adjustments of the various movable pieces of mechanism with which the energy comes into contact. If we go back to inquire how the water came to be in a position to give off this energy in the first place, we shall find the energy to begin with the sun's rays, which, acting upon the water of a tropical sea, sets up a molecular movement of the water, which results in evaporation. The same heat rays acting upon the air expands it making it lighter. By the simple laws of equilibrium colder and heavier air glides under this light air forcing it upward together with the products of the evaporation, which are thus raised, and then by the winds carried over the land till they are finally cooled, condensed and precipitated in rain. In this case molecular energy, set up in two unlike bodies by the same original force from the sun, but acting in different ways on account of the difference of the physical forms of the mediums acted upon, ends by becoming molar or mechanical energy. Any other form of mechanical energy, as steam power, horse power, or man power, may be traced back to molecular motion in the burning of fuel, or the consumption of food in the first place, and to the solar radiation in the production of vegetation at last. In short, the most of the forms of energy that we find on earth are traceable to the solar radiations, and all are, in fact, at bottom only one. The forms taken are transient and temporary, but the aggregate amount is constant.

As mentioned above, some of the names of forms of energy are only the names of phenomena. Such are *heat*, *light* and *sound*. These are only sensations of ours; that is, pieces of our minds. We *feel* the heat, *see* the light and *hear* the sound. Most other animals do the same, and most plants are affected by heat and light in a way which forms the basis of our senses. Indeed, even minerals suffer the effects of what we, in a loose way, call heat and light, but at any rate these terms properly apply, only, to a class of motions called *mental*, and when molecular vibrations do not end by giving rise to this class of motions, these terms are inaccurate and are used only because convenient. A body may be in a condition of violent molecular vibration, but the word *hot* does not express this, but only our sensation of it. The same is true of *light* and *sound*.

The motions, as they happen outside of ourselves, are, in the case of

sound, the vibrations of various elastic bodies. The vibrations are transferred from one body to another, each body vibrating according to its peculiar structure as to shape and materials. In order that we may hear these vibrations they must strike upon the tympanum of our ear. They do this by means of the air; any vibrating body communicating its vibrations to the air, which in turn communicates them to the ear drum. The sensation of hearing is, however, in the brain, and it gets there by the vibrations striking upon the sensitive organs in the internal ear, and being changed there into nerve currents which flow up to the brain and agitate certain brain cells. The nervous current is therefore one of the forms which the energy of vibratory motion takes, or rather it sets up motion in the nerves and then ceases as vibratory motion of air. The measurement of the energy involved in molar motion has been definitely and satisfactorily made by numerous experiments and calculations. The unit of this measure used by physicists is generally the *Kilogrammetre.* The Kilogram, or 1,000 grams, is a French measure of weight, equal to $15.432\frac{35}{100}$ English grains, or close to two pounds Avoirdupois, and the metre is a measure of length equal to $39\frac{371}{1000}$ inches. The kilogrammetre is the power necessary to raise the kilogram one metre high, or the power derived from allowing a kilogram to fall a distance of one metre.

If we raise a kilogram two metres high there will be two kilogrammetres of energy expended in getting it there; if we raise it four metres high it will take four units of energy to do it. If we raise it 19.6 metres (which is equal to $64\frac{1}{3}$ feet) we shall have used 19.6 units of energy to do the work, and if the body should fall back it would return that much energy. In falling that distance it would consume *two* seconds of time, and at the instant of reaching the ground it would be moving at a rate of 19.6 metres per second. If the operation be reversed, it is obvious that any force which is used to project the body upward must start it off with a velocity of 19.6 metres per second. But if the velocity with which it is thrown up is only half as great, the hight to which it will ascend is not the half of 19.6 metres, but only *one-fourth* of that hight or 4.9 metres. Consequently to reduce the initial velocity to *one-half* is to reduce the energy to one-fourth. We therefore perceive that the *energy* is in proportion to the *square* of the *velocity.* The following formula will cover all cases: Let $V =$ the initial velocity in metres per second and M equal the mass or weight of the body in kilograms. Then the mass multiplied by the square of the velocity and the product divided by 19.6 (or $M V^2 \div 19.6$) will equal the energy in kilogrammetres. And $V^2 \div 19.6 =$ the hight in metres to which it will go if thrown up. It can be neatly shown how the energy of a body shot upward is changed from energy of motion to energy of position every instant during its ascent.

Thus suppose a kilogram starts upward with a velocity per second of 19.6 metres. This speed then represents its energy of motion. At the end of one second it will have gained an altitude of 14.7 metres and will be going only 9.8 metres per second. This 9.8 metres *velocity*, as shown above, is good for an additional *ascent* of 4.9 metres, so that at the end of one second the kilogram has an energy of *motion* equal to 4.9 kilogrammetres and an energy of *position* of 14.7, or 19.6 in all, just what it started with. At the end of the second second it has reached a hight of 19.6 metres and has ceased to move, all its energy being now energy of position. As stated before, if the body falls down, all the energy required to raise it up may be converted into heat. Experiments have shown that if a kilogram were to fall 424 metres the energy developed would be sufficient to raise one kilogram of water one degree centigrade in temperature. One heat unit is therefore said to be equal to 424 units of energy or kilogrammetres. We thus see that a definite amount of work or of the motion of a body in a mass is convertible into an equivalent and equally measurable amount of heat or the motion of matter by molecules. Heat is likewise convertible into molar or mass motion, as shown in the expansive force of hot air and steam, &c. The hight of a body above the point to which it may possibly fall is called its Potential. Mass × Potential = Work or Energy. The forms of Energy which most affect organic beings will be discussed briefly in chapters to follow, and the manner in which we have been influenced, differentiated, controlled, and operated by them will be pointed out as far as possible. It is entirely immaterial to my present purpose whether the current theories of the several forms of energy are correct or not. For example, it makes no difference whether *sound* is the vibration of air, iron, &c., or the vibration of the hypothetical *ether* of which we shall hear, or the effect of small particles of matter hurled from a sonorous body. In any event it is the result of force of some sort, and a style of force that has made its mark on animal life. In treating of these forces, then, it will be best to use the most approved theories, and reserve criticism to a later period.

CHAPTER XXXVI.

ELECTRICITY.

If anyone will lay a piece of paper on the table and rub it vigorously with the dry hand for a few moments, it will be found to be electrified as well as somewhat heated. If it be pressed against the wall it will hang there for some moments from the force of attraction. If it be held near any light body, as a bit of cotton-lint or string, it will attract it, and after holding it in contact with itself for a time it will re-

pel it. This quality, called electricity, has been imparted to the paper by the rubbing, and is, in fact, a new form of energy derived from the energy of the rubbing. When the visible motion of the rubbing has ceased, its equivalent in energy persists in the form of heat and electricity. Electricity, therefore, as well as heat, is a mode of energy. And this may, in the case of either, be energy in action or, when restrained, simply energy of position. There are several conditions in which electricity is commonly said to exist, such as current, positive, negative and neutral. Positive and negative are sometimes spoken of as two separate "fluids;" and they were also formerly designated as "vitreous" and "resinous." When a glass rod is rubbed with silk the vitreous or positive electricity is accumulated on the glass, and the silk becomes negative. If a stick of sealing wax be rubbed with silk, negative or resinous electricity accumulates on the sealing wax, while the silk becomes positive. Electricity becomes current when the body in which it is generated is connected with the earth or with any neutral body, the current leaving the body in which it is generated at the positive and negative ends. An electrical machine, of the frictional kind, having its prime conductor connected with the earth by a chain, will give off a constant current of positive electricity while it is being worked. But it will likewise give off a current of negative electricity flowing to the ground. If there be no outlet from the prime conductor the positive electricity is collected upon it in a state of strain or *tension*, while the negative is conducted off in a current to the ground. A state of tension is a condition of potential energy, like a spring wound up. The mechanical motion which is arrested by the friction of the rubber on the glass of the machine is the origin of the electrical energy in this case. There is a strict analogy between the potential of gravitation and that of magnetism and electricity. As before remarked the potential of gravitation is the hight to which a body is raised, and the potential energy is measured by the amount of work it would require to raise it to such hight. "If a common bar magnet be taken in the hand and moved near a powerful fixed magnet, work will be done. If like poles are near each other a force of repulsion is exerted and the muscles are called upon to do work in bringing the magnet nearer to the fixed magnet, moving it against this force."[1] The position to which the magnet is moved in this way by muscular work, is a position of potential energy. And if the magnet be released (provided it is not allowed to turn end for end) it will be repelled with an active energy exactly equal to that which was expended in moving it up. The positive poles of two magnets repel each other, and so do the negative poles—but the positive poles attract the negative, and vice versa. If force be used to sep-

[1] Electricity and Magnetism, J. B. Murdock.

arate two attracting poles, the position in which they are left, with reference to each other after the exertion of such energy, will be a position of potential energy. In each of these cases the measure of the energy is the potential position multiplied by the force of the magnet. If the fixed magnet possess twice the force it will exert twice the energy, the potential position remaining the same in each case.

The same principles govern in electricity. If a unit of positive electricity be moved near a larger quantity also positive, it will be repelled, and if released the unit quantity will fly off, doing work equal to that required to bring it up. The point to which it is brought is its potential, and it is evident in this case equally with the other cases, that the energy with which it will leave this potential will be in proportion to the quantity of the electricity, two units being repelled with twice the energy with which one is repelled. When we know the amount of work required to move a body into a potential position, and the force against which it is moved, we can find the value of the potential by the following formulas:

$$\text{Gravitation potential} = \frac{\text{Work done in lifting weight.}}{\text{Weight lifted.}}$$

$$\text{Magnetic potential} = \frac{\text{Work done in moving magnetic pole.}}{\text{Strength of pole.}}$$

$$\text{Electrostatic potential} = \frac{\text{Work done in moving quantity of electricity.}}{\text{Quantity moved.}}$$

Potential is therefore measured by work. At infinite distances all attractions and repulsions cease. If any of them ceases at a finite distance, that point is a position of a zero potential. The electrostatic potential at any point nearer than the zero point is measured by the work required to bring a unit quantity of positive electricity to that point from the zero point.

Potential energy always tends to unwind and run down to zero; a weight falling to the ground if not prevented, and a magnet pole moving away into a less potential position if it is near another of the same name. In any electrified region the direction in which a unit of positive electricity tends to move shows the direction of lower potential. It will either move away from a positive electricity or towards a negative electricity, and work will have to be done to move it towards the former and to restrain it from going to the latter.

Induction is due to the following facts: 1st, There is around every magnet, whether a permanent or electro magnet, a field of force, which is constituted of lines of force or electrical motion. About the permanent magnet these lines of force curve away from the north pole and make a circuit and return to the south pole. If a bar magnet be covered with a piece of paper and fine iron filings be sifted over it they will be arranged in these lines of force so far as that one plane is concerned, but we are to understand that if the bar were turned on edge and the
held
tract it, ...

paper were to be laid upon the edge at right angles to its former position, similar lines of force would be obtained there. And the same is true of a plane at any intermediate angle. If the lines of force could be seen

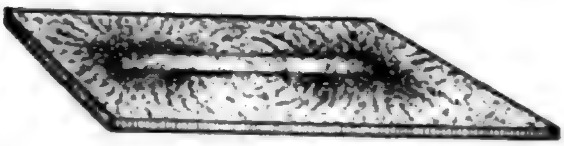
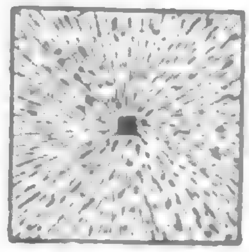


FIG. 131.



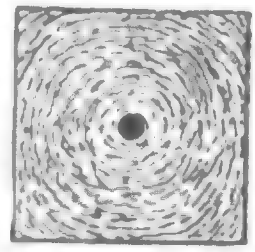


FIG. 132. FIG. 133.

FIG. 131.—*Lines of Force* of a permanent *Bar Magnet.*

FIG. 132.—*Bar Magnet* seen end-on showing radiating lines of force.

FIG. 133.—Whirls of *Lines of Force* around a wire carrying a current seen end-on.

end-on they would appear to radiate in all directions from the pole of the magnet. (See fig. 132.) If a piece of paper be peforated in the center and a wire conducting a current of electricity be passed through the paper at right angles, fine iron dust sifted upon the paper will take the form of concentric circles about the wire. (See fig. 133.)

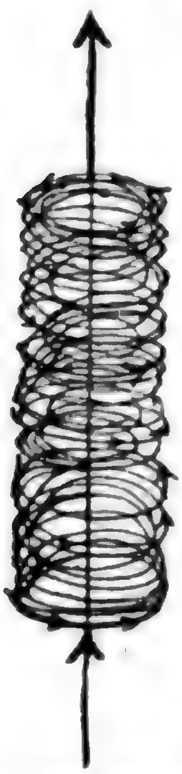


FIG. 134.

FIG. 134.—Same as 133 seen sidewise.

Around every direct current there is a field of magnetic whirl something like that shown in fig. 134. There is a reciprocity between the current through the wire and the whirls of force around it. They belong together and either one begets the other. The direct current gives rise to the whirls which endure while the current lasts. And conversely if by any means the whirls can be produced they will give rise to a current which will continue as long as the whirling can be kept up. When a wire ring is moved near a magnet across a space in which there are lines of magnetic force, the resultant of this motion of the wire upon the lines of force is the magnetic whirl about the wire itself, and consequently a current induced in the wire. And this current through the wire will continue as long as the motion of the wire through the field of force continues. When the wire stops moving the whirls and current through it stop.

The foregoing statement is on this proviso; that the motion of the wire across the field of force (in order to produce the current), must cross the lines of magnetic force in such a way that the number of these lines inclosed by the circuit must be constantly on the increase or decrease. If the wire hoop be moved through a uniform field, as in Figs. 135 and 136, in such a way that the number of lines of force passing through the hoop is neither increased nor diminished, no current will be induced. In Fig. 137 the ring is supposed to tilt as it moves and thereby the number of lines enclosed decreases. In that case a current

is produced. And so it is when the ring is transferred from a dense field to one less dense, the current in these cases taking the positive direction; that is, opposite to the direction of the hands of a clock (when you look from the point toward which the lines of force run). If the transfer is made to a field in which the lines run in a contrary direction, the current is generated, as in fig. 138. (See S. P. Thompson.)

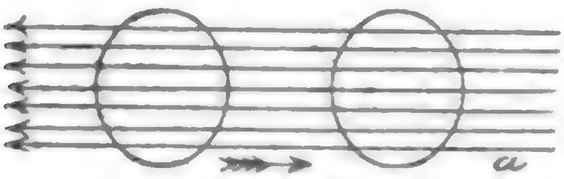


FIG. 135.

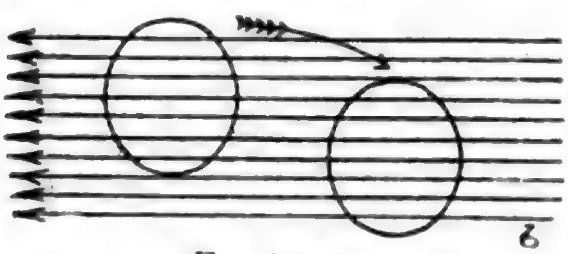


FIG. 136.

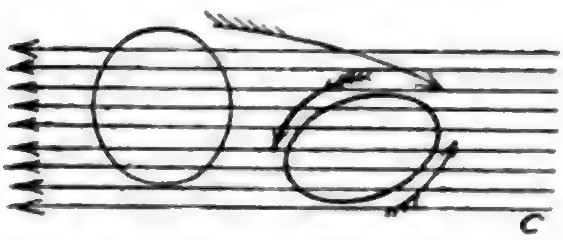


FIG. 137.

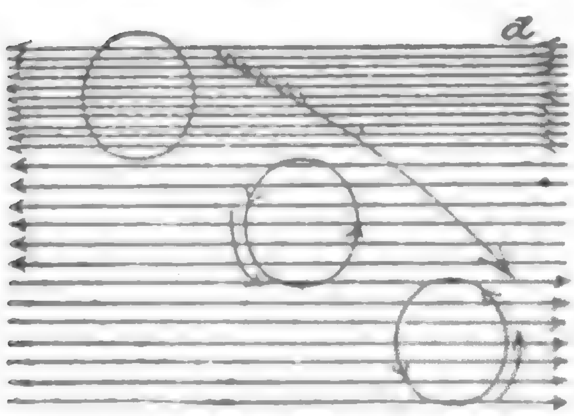


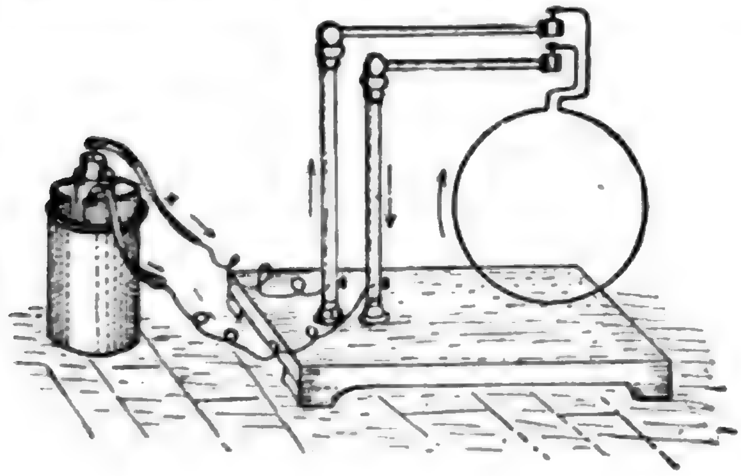
FIG. 138.

It thus appears that a part of the energy of an electric current exists in the form of whirls in the space surrounding the conductor, and it is through the process of the excitation of these whirls that the induction currents are developed, which excitation is caused by the motion of the wire in a mass; which motion requires the expenditure of work or energy. We here see the conversion of visible energy of motion into electricity. The more rapid the motion the stronger the currents will be. Approach of the coil causes a current in an opposite direction to that caused by its recession. The stronger the magnetic field into which the coil is introduced the stronger will be the induced current. In order to produce a continuous current it is obviously necessary to move backwards and forwards in the field of force so as to keep up continuous motion of the coil within the field; hence, currents obtained that way are alternating in direction. In some forms of the electric dynamo, for lighting, &c., these alternating currents are all made to flow in one direction by the use of "commutators."* In generating the currents the longer the conductor used to move in the field of force, the stronger the current, whether it be a bar or a coil; and if the latter, the more turns the better, and the less of the conductor that remains outside of the field, the better. The magnet furnishing the field may be either *permanent steel* magnet, or *electro magnet.* The latter is commonly used in the ordinary dynamo.

The control which the earth has over the magnetic needle is supposed

* This is the case with the Brush dynamo, and all dynamos used in electrolysis. The Westinghouse, and others are alternating current machines, no commutators being used.

to be due to electric currents flowing around the earth from east to west. These currents are produced by the variations of temperature, which take place everywhere daily in consequence of the revolution of the earth on its axis, showing new parts constantly to the sun. If a magnetic needle be brought near a wire carrying a strong current of electricity, it will tend to place itself at right angles to the current. If an experimenter should hold the wire in his hands and above the needle, the current running from left to right, the positive pole of the needle would point away from the person holding the wire. If the wire were held under the needle it would point towards the holder. If the current ran in the opposite direction the phenomena would be reversed. The reverse of this experiment is equally true; viz., if the magnet be fixed and the wire carrying the current be free to move, it will tend to place itself at right angles to the magnet. Fig. 139 represents an apparatus consisting of a hoop of wire suspended upon points which are



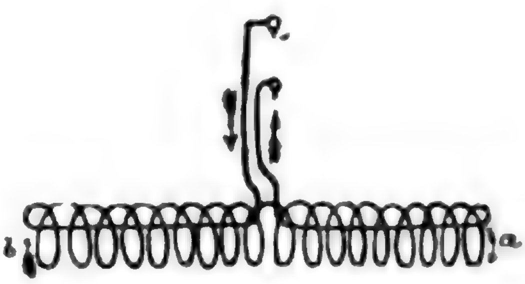


FIG. 140.
A *Solenoid.*

FIG. 139.

inserted into cups containing mercury, so that it is free to revolve without disturbing the connection. If this hoop be placed so that its plane coincides with the magnetic meridian of the earth, and then a current of electricity be passed through it, it will turn on its suspending points and place itself at right angles to the meridian, and take such position that the current in the lower part of the hoop will flow from east to west, the same direction taken by the surface currents of the earth. Fig. 140 represents a solenoid. This consists of a wire coiled into a double helix and suspended by points, upon which it can turn. When a current is passed through the helix it acts in the same way as a magnetic needle, taking a north and south position in such a way that the current in the bottom part of each coil is flowing from east to west, so that the end marked (*a*) becomes the north pole and points to the north.

Two parallel currents going in the same direction attract each other bodily, that is, the wires carrying them tend to approach each other. If the currents are in opposite directions they repel. In two hoops of wire made to float and convey currents, if both go alike, either in the direction of the hands of a watch, or the contrary way, they will move

toward each other. If the currents go different directions they will float apart.

From what has gone before it is not difficult to see that a magnet is simply a body under the influence of electricity. According to Ampere's theory, there are currents of electricity flowing around all the ultimate molecules of the magnet, in the same direction. Those currents around molecules in the interior of the magnet, neutralize each other so that the final effect of all the molecular currents is the same as that of a set of surface currents flowing around the magnet in such direction that if the magnet be standing with its positive end toward the north, the current passes toward the west on its underside, and toward the east on its upper side; in other words, in the direction of the hands of the watch when it stands on edge with its back toward the north.

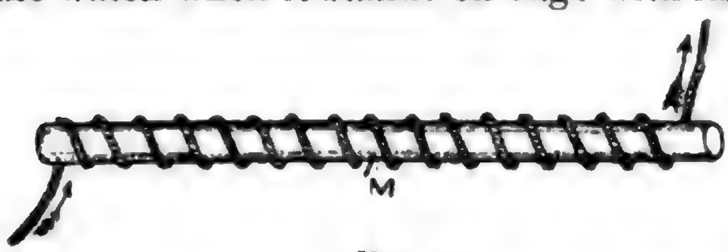


FIG. 141.

FIG. 141 —Bar of soft iron made into a temporary magnet by a coiled current.

If a bar or rod of soft iron be wrapped with a coil of insulated wire carrying a current of electricity, the bar becomes an electro magnet. We have seen that electric whirls about a wire produce a current in such wire. If the wire be a short piece not connected at each end so as to allow a current to pass, it will merely possess tension at each end and will then be a temporary magnet. A soft iron bar ceases to be a magnet as soon as the current in its surrounding coil ceases, but if a steel bar be thus magnetized by a coil, its magnetism remains permanent. In every magnet or magnetized body the motion set up in its molecules and its surrounding field appears to be centifugal in a lateral direction, and centripetal or contracting in a longitudual direction. "Nairne had observed that metallic wires submitted to discharges of static electricity underwent a diminution in their length. M. Edmond Becquerel found that this diminution was inversely proportioned to the cube of the diameter of the wire."[1] After a wire has been brought to incandescence by a persistent current, it is found to have lost 5 or 6 per cent. of its length, the current having opposed the cohesion of the metal, and compressed the molecules of the metal together in a longitudiual direction. (See chapter on muscles.)

The attraction which magnets possess for certain substances is an exemplification and further evidence of the contractile tendency of the force in certain directions. Bodies are attracted toward either end of the magnet, so that if a magnet be bent into the shape of a horse shoe, a bar may be placed so as to be attracted at one end to the positive pole of the magnet and at the other end to the negative pole. Such a bar completes the circuit of the magnet and is called an armature. The

[1] Gaston Plante Storage of Electrical Energy, 243.

action in a magnet which prepares the way for and which precedes the the drawing of a body to it, is the creation around such body of the magnetic whirls and the consequent formation in it of a central line of force, the ends of which constitute its poles, or tension extremities. And since positive attracts negative, and vice versa, the negative pole of the attracted body will be found next the positive pole of the magnet,

FIG. 142.

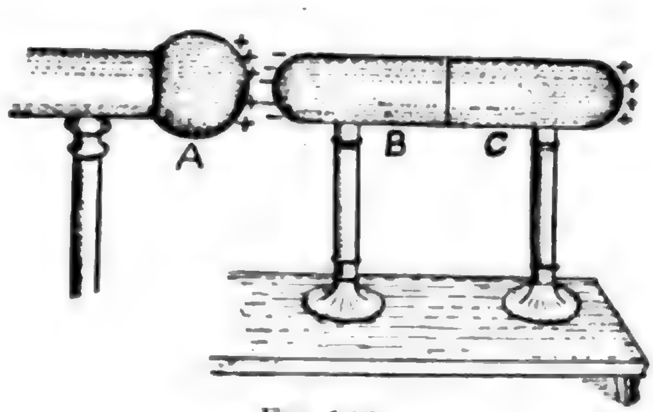


FIG. 143.

FIG. 142.—*Horse Shoe Electro Magnet.*
M.—*Soft-iron bent bar.*
A.—*Armature.*
It is a magnet only while the electric current passes through the wire with which the spools are wound.

FIG. 143.—*Illustrating Electrical Induction.*
A.—Prime Conductor of an Electrical Machine.
B, C.—Cylinder jointed in the middle and insulated on glass legs.

as in the case of the armature of a horseshoe magnet, the positive pole will be at the negative end of the magnet. This action of a magnet in establishing polarity in a separate body is called *induction.* Induction takes place whenever an electrified body is brought near a neutral one and is the preliminary part of attraction. If the prime conductor of an electrical machine be brought near a metallic cylinder insulated as in fig. 143, the cylinder is instantly rendered polar, the negative tension being

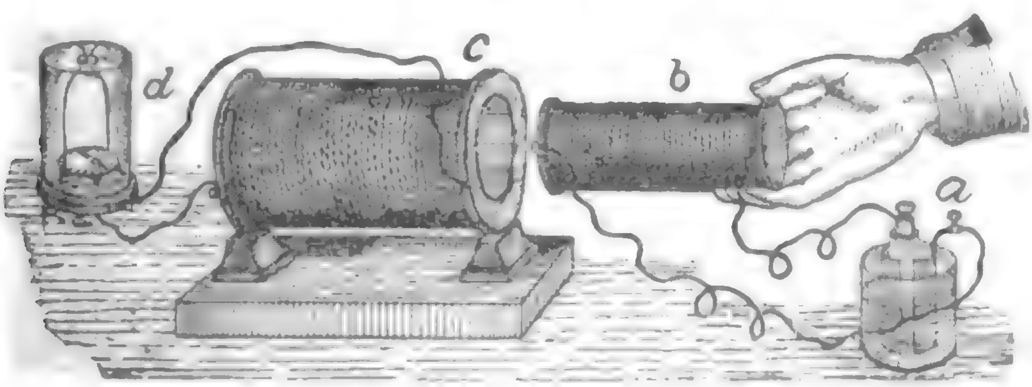


FIG. 144.

FIG. 144.—*Induction by a Battery and Current.*
a.—Battery.
b.—*Induction or Primary Coil.*
c.—*Secondary Coil or Conductor.*
d.—*Galvanometer.*

in the end next the positive pole of the machine, and the positive tension at the further extremity of the cylinder. If the positive end of the cylinder *C* be drawn away from the other it will be found to represent a position of potential energy in which the electricity being positive tends to run down to the level of that of the earth.

Figure 144 illustrates the production of a current in a coil of wire called the conductor, by induction from the action of another coil connected with a battery and passing a current. The apparatus is so arranged that the battery coil can be inserted inside of the spool of the conductor coil. The current can be suddenly opened or closed by disconnecting the wire from the battery or connecting it. Suppose the primary coil to be near or inside the conductor coil, and the current to be suddenly made by connecting the wire of the primary coil with the battery, then a momentary current will pass through the conducting coil, and this current will go in a direction opposite to that which circulates through the primary. After this there will be no further current through the conducting coil until the current which has been meanwhile passing through the primary, or battery coil, is suddenly disconnected or opened, then there is another momentary shock or current through the left hand coil, and this time the current is in the same direction as the one in the right hand one. So when the connection is *made* in the right a shock occurs in the left in the contrary direction; when it is broken, shock occurs with current in same direction. The same effect is produced when the right hand coil is moved towards the left hand coil, or is pulled away from it. Moving *towards* produces a contrary current in the left coil, same as closing or making the current. Moving from causes the current in the same direction. In this case the current continues while the motion of the right hand coil is kept up, provided the two are always so near that the left coil is within the *field of force* of the battery coil. The principle upon which the current is produced in this case is that of the conversion of molar motion into electricity by the change of position of the left hand coil with reference to the field of force in the right hand one as explained above. When both coils are still and the current is suddenly opened or closed, the principle is the same, the effect being as if the left hand coil were suddenly brought into the presence of the current and stopped there, or suddenly taken out of it; the current in the left hand coil continuing only as long as the process of starting or stopping the circuit in the battery coil, a very small fraction of a second. When the primary coil is moved to and from the secondary one, the more rapidly it is moved the stronger will be the currents induced in the secondary. If the primary is inserted in the secondary and the current generated in the latter by rapidly making and breaking the circuit in the former, this can obviously be done much more rapidly than the primary could be inserted and withdrawn, or moved in any way bodily near the secondary. As making and breaking the circuit is the same as moving the coil bodily, the more rapidly it is made and broken, the more powerful is the generated secondary current. Hence there have been many contrivances made for this purpose. One

constructed by Gordon completes the circuit 6,000 times in a second and breaks it as often. The advantage of the induction apparatus is that the current of a voltaic battery which has large heating and chemical power with *low potential*, is exchanged for an electrical current of low chemical and heating power, but very high potential. So that while it is possible to get only a short spark from a voltaic circuit, the same current is able to induce a secondary current which will give a spark several hundred times as long. Induction machines have been made to deliver a spark over three feet long. The case of the induction current is no exception to the rule that energy is required to produce energy. Because when the coil from the battery is moved *toward* the conduction coil, or left hand coil, the current induced in the latter is *contrary*, and contrary currents *repel* bodily, so that as soon as the current is produced the repulsion commences. In other words, the molar motion of the coils, or coil, is converted into a repellent current, and the molar motion is resisted and at the same time heat is developed in the conducting coil. If a metallic top be set to spinning near two iron poles which can suddenly be converted "into the poles of a powerful electro-magnet," when the poles become magnetic by a current through them the top is soon brought to rest. The reason is that the magnetic currents in the magnet produce in the top—which is a conductor—alternately, on its revolving surface approaching and receding from the magnet, a series of secondary induced currents, which by their repellent power tend to turn the top backwards, and this effort results in converting the energy of the currents into heat, the same as if the top were stopped by friction. But it is observed that if the top in this case were compelled by force to turn continuously in the presence of this current, and wires contrived to conduct away the electricity induced in it, we should have a continuous (alternating) current from the top. In fact, we should have an electric dynamo to all intents and purposes.

A dynamo usually consists essentially of series of bobbins or coils of wire fastened upon the periphery of a wheel, which is made to revolve between the poles of powerful magnets. In the earlier machines the magnets used were strong, permanent, steel magnets. In the later ones, the magnets are electro-magnets. These electro-magnets were at first charged by small side dynamos, which revolved in the presence of permanent steel magnets, and the great currents used for lighting, &c., were generated by the bobbins revolving between the great electro-magnets so charged. But after awhile it was discovered that after the great electro-magnets were once charged the charge did not entirely leave them when the current around them was discontinued. So that when the bobbins were revolved in their presence a slight current was created through the bobbins. It was then suggested to run this current

around the great magnets, and thus supply them with additional force, which being done the current sent off from the bobbins at once greatly increased. Some of the dynamos now in use adopt this plan, a part of the current generated in the revolving bobbins being switched off or "shunted" from the main current and made to run around the electro-magnets and give them greater force, which greater force reciprocally acts to increase the main current. The part of the main current not returned to reinforce the electro-magnet passes on to do the work of electro lighting, &c.

Two conductors separated by an insulating body in a thin stratum, is an *Electric Accumulator.* A Leyden jar, is an example. The two conductors are the electrodes, and the insulator is called a dielectric. Thus in the Leyden jar, the layers of tin foil are the electrodes, the glass is the dielectric.

Conductors. The passage of electricity from its potential to a neutral position is much more rapid in some than in other bodies; the time elapsing after the discharge before the potential is uniform over the whole body, being very different in different bodies; this difference indicating difference of resistance. All metals are good conductors, but not alike. The resistance of lead is 12 times that of copper or silver; iron is 6 times that of copper or silver; mercury is 60 times that of copper or silver. The higher the temperature of metals the greater is the resistance. All liquids containing water, and all damp bodies, are conductors, inferior to metals, and cannot be used for insulators. Gases at the atmospheric pressure, whether dry or moist, are insulators so nearly perfect, when the electric tension is small, that there is no evidence, as yet, of electricity passing through them by ordinary conduction. When electricity passes through gases, it is by disruptive discharge on account of high tension. The electric strength of a dielectric or insulator, is the value of the electromotive force which can exist in a dielectric without causing a discharge. The electric strength of air diminishes as the pressure is reduced from the atmospheric pressure to that of about three millimetres of mercury. "When the pressure is still further reduced the electric strength rapidly increases, and when the exhaustion is carried to the highest degree hitherto attained, the electromotive force required to produce a spark of a quarter of an inch, is greater than that which will give a spark of eight inches in air at ordinary pressure.' (Clerk Maxwell.) The most perfect vacuum yet formed is an insulator of very great electric strength. The electric strength of hydrogen is much less than that of air. Cold glass is a good insulator, but when hot, say 200° F., is a conductor. Gutta-percha, caoutchouc, vulcanite, paraffin and resins are good insulators, the resistance of gutta percha at 75° F., being about 6×10^{19} (ten 19th

power) times that of copper. In the following list each substance conducts better than any one of higher number :

Good Conductors.

1 Silver.
2 Copper.
3 Other metals.
4 Charcoal.
5 Water.

Partial Conductors.

6 The body.
7 Cotton.
8 Dry wood.
9 Marble.
10 Paper.

Non-conductors or Insulators.

11 Oils.
12 Porcelain.
13 Wool.
14 Silk.
15 Resin.
16 Gutta-percha.
17 Shellac.
18 Ebonite.
19 Paraffin.
20 Glass.
21 Dry air.
22 Vacuum.

Ice, crystals, and solidified electrolytes are insulators. Naptha, turpentine and some oils are insulators—not the most perfect.

The *electric-glow* occurs when a conductor terminates in a point, projecting into air and not near another conductor. The tension compels a discharge into the air, into which the electricity, spreading in proportion to the square of its distance, soon reaches a point, or rather a surface, of air whose resistance prevents further dispersion, except as the air itself is driven away, creating an electrical wind. Such passage of electrified particles is called electrical convection.

The *electric brush* consists of ramifying discharges into the air from a blunt point or a small ball. The tension in this case diminishes less rapidly with distance from the conductor, than in the other case.

Electric tension is the stress or strain in a conductor of accumulated electricity against an insulator or dielectric which bars its exit. "Thomson has found that air, at the ordinary pressure and temperature, can support an electric tension of 9,600 grains weight per square foot, before a spark passes." (Maxwell.)

Induction is the creation of tension and polarity in a medium by means of an electromotive force in a neighboring body. They both cease upon the removal of the body in which the electromotive force is displayed. Notwithstanding the fact mentioned above, that the space in a vessel completely exhausted of air, is about the most effectual *non-conductor* known, the power of *induction* across such space is not lessened a particle. This emphatically points to a "medium" remaining in space after all ponderable and visible bodies are removed from it. This medium is called *ether* by physicists, and its extension throughout space is attested by the fact that electrical induction takes place across the empty space between the sun and earth, a distance of 94,000,000

miles. When a body is at a temperature of 250 degrees C. it may be called warm; 500 degrees C. it may be called hot. At 1000 degrees C. we have the heat rays; at 1200 degrees C. we have the orange rays; at 1300 degrees C. we have the yellow rays; at 1500 degrees C. we have the blue rays; at 1700 degrees C. we have the indigo rays; at 2000 degrees C. we have the violet rays. So that any body raised to a temperature of 2000° C. will give us all the rays of the sun.

Incandescent electric lighting depends on the principle that a bad conductor becomes heated during the passage of an electric current, and when heated (to a sufficient degree) emits light,[1] or rather when the degree of vibration has become great enough the effect of the extra high vibratory rate is *not heat* but light. When a carbon rod, a piece of platinum wire, or thin iron wire, forms part of a circuit, it glows with an intensity of light dependent upon the strength of the current and the resistance offered by the bad conductor. If the bad conductor be cut in two and the two halves be brought into contact, the current passing through will give the glow. Now, if the two be slightly separated the current will pass across the separating space producing what is called the voltaic arc. The brilliancy of the arc depends upon the strength of the current, the material composing the electrodes, or points between which the light is produced, and the atmosphere about it. With potassium or sodium electrodes the light is more brilliant than with platinum or gold. With sodium the color of the arc is yellow, with zinc and magnesium it is white, while with silver it is green. The[2] spectrum of the arc produced between silver and carbon contains only two green bands, and if other metals be substituted for the silver, the spectrum is always "discontinuous"—being a few color bands separated by dark spaces. (The spectra of gas and oil flames are continuous, but red, orange and yellow are predominant, there being little green, less blue and still less violet, or none at all.) In the electric arc, where both points are carbons, the light from the carbons is white, the same as sunlight, that is, contains all the colors, while the light of the arc itself is violet-blue, its spectrum containing an excess of violet, less of blue, and scarcely any of the colors of the lower end of the spectrum. The electric light depends for its direct development upon mechanical energy and not upon combustion, as do gas, oil, &c., consequently no carbonic acid gas results from it. The chemical action of the electric light is the same as that of the sun. It causes the combination of chlorine with hydrogen, decomposes chloride of silver, and can consequently be utilized in photography, and it imparts phosphorescent properties to susceptible substances. It takes two and a half times

[1] See Paget Higgs Electric Light, p. 55.

[2] For spectrum and spectrum analysis see Chap. on Light.

longer to take a photograph with it. The electric arc does *not heat.* This appears astonishing at first, for all bodies fuse or volatilize when introduced into the arc."

"The voltaic arc is the result of the incandescence of a jet of particles detached from the electrodes or poles and thrown from one electrode to the other, particularly from the positive pole to the negative pole. The positive electrode has a temperature much higher than the other, the negative electrode being barely red when the positive electrode is at a white heat. The positive pole is consumed at double the rate at which the negative pole disappears when the carbons are equal in size." When both electrodes are carbon points, the arc is egg-shaped. "It appears as a flickering flame, and brilliant particles are constantly carried between the two electrodes." When there are mineral impurities in the carbons, they are fused and appear as melted globules upon the carbon points. "The voltaic arc behaves precisely as any other portion of the electric circuit. It is attracted or repelled by magnets in an exactly similar manner. Indeed the incandescent particles constitute between the two electrodes a conductor of great mobility; and the arc may be regarded as a badly conducting chain of these particles, raised to incandescence in consequence of the resistance they offer to the passage of the current."

We have the following immediate *Sources of Electricity: Friction. Percussion:*—As when one substance is struck violently by another—one becomes positive, the other negative. *Vibration:*—As of a metal rod. *Disruption* and *Cleavage:*—As when a card, a paper collar, &c., is torn asunder, lumps of sugar crunched, sudden cleavage of a sheet of mica, &c. *Crystallization* and *Solidification:*—Many substances passing from a liquid to a solid state—as sulphur, chocolate, arsenic acid, sulphate of copper and potassium—give off electrical action. *Combustion:*—As burning charcoal, &c. *Evaporation:*—When evaporation takes place the vapor takes one electrical state, and the remaining liquid the other. "A few drops of a solution of sulphate of copper thrown into a hot platinum crucible produce violent electrification as they evaporate." When water is turned into vapor the vapor becomes positively electrified, (hence the charge of positive electricity in the warm, tropically-originated, summer cloud.) *Pressure:*—Many substances become electrified when pressed. Cork becomes positive when pressed against amber, gutta-percha and metals, but negative when pressed against spars and animal substances. A crystal of calc-spar pressed along its blunt edges, between the dry fingers, becomes electrical, and remains so for some days. *Pyro-electricity* is a name given to electricity developed upon the heating or cooling of certain crystals, especially Tourmaline, which, when heated, attracts light bodies. Sili-

cate of zinc or "electric calamine," boracite, cane-sugar, quartz, tartrate of potash, sulphate of quinine, and some others are pyro-electric.

Electricity is generated in most if not all *animal tissues*, and it is thought vegetable tissues, too. And some animals and some vegetables possess specially adapted organs for storing electricity. (See Chap. on Electric Organs.) *Thermo-electricity:—Heat* applied at the junction of two dissimilar metals, causes a current across the junction.

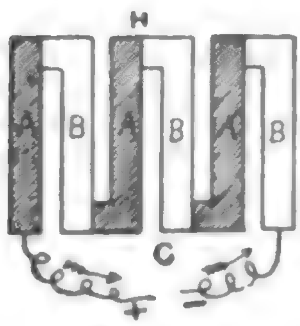


FIG. 145.

FIG. 145.—*Thermo Electrical Battery.*
A, A, A.—Bars of *Antimony*. H.—Heated end of the bars.
B, B, B.—Bars of *Bismuth*. C.—Cold end.
The current travels in the direction of the arrows. If the wire be cut there will be tensions at the ends, shown by the signs +, −. The battery can be made by any two metals arranged as in the fig. If the two ends of a crystal of Tourmaline be united by a wire and the crystal then heated, a current will pass through the wire, and it becomes a thermo-electric battery.

Contact of *dissimilar metals* produces electricity. In the following list each metal is positive to those below it, the amount of the difference of potential being stated in volts:

		Diff. in Potential in volts.
+	Zinc } Lead }	.210
	Tin	.069
	Iron	.313
	Copper	.146
	Platinum	.238
−	Carbon	.113

The difference between two not contiguous is obtained by adding together all between. Thus between zinc and carbon the difference of potential is 1.089 volts.

There is a difference of potential between two dissimilar liquids when brought into contact; also between a liquid and a metal; also between a hot and a cold piece of the same metal. *All* chemical action produces electrical action. In fact, chemical action itself is held by many chemists to be a form of electrical action. Galvanic batteries are contrivances for converting chemical action into current electricity—or rather for gathering up the electricity generated by chemical action and running it off into a current. To sum up—"the most important agencies in the production of electrification in bodies, are friction, heat, chemical action, magnetism, and the contact of dissimilar substances." (S. P. Thompson, 71.)

Atmospheric Electricity. Professor Vander Mensbrugghe in a memoir on the application of thermo-dynamics to the study of the variations of the potential of liquid surfaces, is led to a conclusion of capital importance to meteorology. His equations, namely, seem to prove vigorously that any change in the surface of the liquid gives rise to a change of

temperature, and if the circuit is closed, to a thermo-electric current. His experiments show that on the one hand the water of the ocean under the action of the sun being submitted to a continual evaporation must affect the calorific and the electric state of the earth, and develop constant thermo-electric currents. On the other hand the enormous quantity of vapor which is lifted into the atmosphere is there subjected to incessant variations in respect to the surfaces of contact with the air, of its vesicles, rain-drops, &c. Its reduction from a state of extreme and almost molecular tenuity to a state where by sudden condensation it forms larger rain-drops, enables it to actually produce enormous quantities of electricity until the drops fall in turn upon the surface of the globe from which they were elevated. Thus we have at once on the one hand the existence of a constant source of the thermo electricity circulating around the earth, and on the other hand a permanent cause of atmospheric electricity. (*Harper's Annual Record, 1876.*)

The fact is, there is no sort of motion whatever that is not accompanied by electrical action. If there is such a substance as *ether* pervading all space, including the pores and intermolecular openings in ponderable bodies, certainly when we see the ponderable bodies move we can easily believe their enclosed ether moves too. That this ether is the vehicle of *heat*, *light* and *induction*, is as good as proved. That it is the body which moves in the case of current electricity, and the body which is on a strain when positive and negative tensions are exhibited, is at least a reasonable hypothesis. We have seen that no sort of motion can end partly or wholly without setting up another sort. As the ether is the most mobile of all bodies, the motion of other bodies is communicated to it on all occasions. No ponderable body can move without subjecting its enclosed ether to new conditions as to contact, heat, pressure, friction, and the different electrical states of the other bodies in its vicinity. These new conditions react upon the ether enclosed in such body to produce new conditions, and hence electrical movements in it.

Gaston Plante considers Electricity to be a purely mechanical motion of ponderable matter, and its discharges to consist in the extremely rapid flow or transport of a very small quantity of matter, whether we consider the electric spark the voltaic arc or electrical discharge in general. The matter discharged, he says, is not electric matter, "but electrified matter borrowed both from the substance itself from which it detaches itself, and from the center (medium) through which it passes." This is without doubt true of many of the *visible effects* of electric action, as the flow of fine particles from one pole to another in the arc light, the electric spark and lightning in the air, the electric glow, electric brush, &c. But behind these phenomena is the energy which produces them,

and that is the motion of some substance far more nimble than the metallic particles of the wire conductor.

Electric motions may take the form of gyratory movements, the same as (other) mechanical motion, by an effect from reaction due from the flowing of matter however small the quantity may be which escapes from electrified substances. But the phenomenon of electrical motion is not exclusively a transportation or discharge of electrified matter; it may become a molecular vibratory movement as other mechanical motion does. This happens when the ponderable matter resulting from the discharge comes in contact with a substance of a peculiar elasticity which permits the transfer and propagation of the shock throughout the mass of the substance. "This peculiar elasticity constitutes electric conductibility. There is not in such case any transport of ponderable matter throughout the length of the conducting substance, but diffusion by vibrations analogous to those of the sonorous motion, or the movement transferred to a series of elastic balls. The phenomenon of the jet of ponderable matter may be also produced at the extremity of the conductor when there is a break or change in material, as for example the conducting wire. This transformation into vibratory motion may take place, to a certain degree, in the electric discharge itself through an imperfectly conducting medium, such as ordinary or rarefied air. There is then both transport and vibratory motion; and it is this double effect which often gives to electric phenomena such complicated appearances.

The phenomena of suction produced by the flow of an electric current of high tension, are analogous to those which result from the passage in a narrow tube of a liquid or jet of steam impelled at a great speed (as in the Giffard Injector). M. D. Colladon has observed an analogous suction or reverse action in water-falls. He says, "There may be perceived little sheaves composed of millions of liquid pearls impelled at a rapidity of motion absolutely incredible, in a contrary direction to the water of the cascade, and quickly ascending towards the summit." Analogous to this says Plante, "The very rapid movement of ponderable matter which constitutes electric discharge produces like the rapid motion of a fluid a suction or inverse motion in the particles of matter which receive the electric shock, or of that which forms the center or medium of the matter traversed by the discharge. From that cause a double movement occurs in two different directions, consequently a double transport of ponderable matter. To this double movement are due the effects produced in electric discharge, which are, by general consent, called *positive* and *negative* electricity. Instead of these expressions, which seem to infer two sorts of electricity, the terms "direct electric motion" and "inverse electric motion" may be substituted. "As to the phenomena produced by electricity called static, we consider

them as due to the vibratory state of the molecules at the surface of electrified substances, accompanied by a more or less abundant emission of material particles detached from this surface, according to the conditions in which the electrified substances are placed in reference to the surrounding medium. The phenomenon of the aigrette (or brush of down) is a characteristic manifestation of this emission of ponderable matter. The aigrette is always produced in a greater or less degree on different points of a strongly electrified substance; the least wrinkle in the surface will occasion it. This phenomenon then reveals the state of continual discharge in which a substance may be when charged with static electricity." "The earlier electricians, principally Boyle and Hankshee, had already allowed that material effluvium escapes from electrified substances. This idea appears to us to be still correct at the present time by adding to it the vibratory molecular motion of the surface of these substances." "It may be also said that this emission becomes more evident the nearer the electrified substance chances to be to another substance not electrified, which serves, in some degree, as target for the projectiles formed by the molecules from the electrified substance." "To sum up in a few words the views herein stated; we think that electricity may be considered as a movement of ponderable matter—a movement of transport given to a very small mass of matter impelled to an extreme velocity, when there is a question of electric discharge—and a very rapid vibration of the molecules of matter when touching its transmission to a distance in a dynamic form or its manifestation in a static form on the surface of substances." (*Gaston Plante.*)

There are numerous analogies between the action of electricity and of other mechanical motion at a high tension, some of which may be mentioned. "The mechanical calorific and chemic action produced at the same time by an electric current of a certain tension, on the surface of

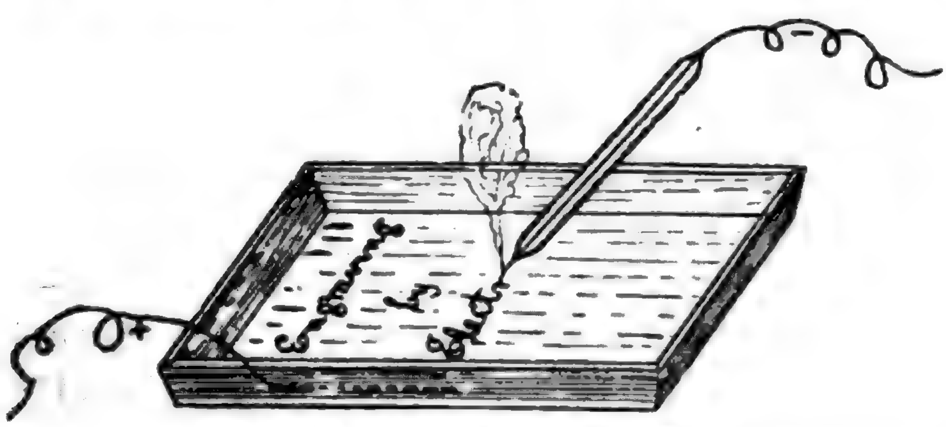


FIG. 146.—*Engraving by Electricity.*

glass, which has led to engraving on glass by electricity, may be compared with the action exercised" by the "sand blast" on glass, in which glass is engraved by a very fine jet of sand shot forth under strong pressure, which has been in use for many years in this country. The process of electrical engraving on glass is briefly as follows: The glass

is laid horizontally in a shallow basin and covered with a concentrated solution of nitrate of potash, which is poured over it so as to cover it. Then, in the layer of liquid which covers the glass, and along the edges of the plate, a horizontal platinum wire is immersed in connection with the pole of a secondary battery of from 50 to 60 elements, then, holding in the hand the other electrode, formed of a platinum wire insulated except at the extremity, the glass covered with the thin layer of saline solution is touched at the points where the letters or drawing are required to be engraved. A luminous track appears wherever the electrode touches, and no matter how quickly they are written or drawn the characters become distinctly engraved on the glass. If one writes or draws slowly the lines are deeply marked, their breadth depending on the diameter of the platinum wire serving as electrode; if it be pointed these characters may be extremely fine." The engraving may be done with either electrode, but with the *negative* one, the engraving is more distinct and it requires a less powerful current. These results have been obtained by the use of secondary batteries (storage batteries), but better, or at least more continuous work, could be got from a Bunsen battery of a sufficient number of elements, or from a dynamo, or even an alternating current magneto-electric machine.

"The phenomena of attraction and repulsion which seem so characteristic of electricity can be imitated with the aid of a strongly compressed jet of air escaping through an extremely narrow opening. Balls of different substances, even metal, may be held in equilibrium attracted or repelled by a jet of air at high pressure according to their distance from the opening, density, &c. The recent works of M. Bjerknes have shown the possibility of also obtaining, by other purely mechanical means, attractions and repulsions similar to those caused by electricity." Perforations in paper by electrical currents resemble those made by projectiles impelled at a high velocity. "A jet of steam projected under strong pressure against the slag of blast furnaces divides it into numberless threads forming it into a kind of mineral wool. In the same way matter impelled by electric movement sub-divides to an infinite extent all other matter it finds in its way." Experiments have been made by Prof. Bjerkness, of Christiania, in which he produced in water, "lines of force" which imitate very closely the lines of force produced by magnets. He used two little drums with India-rubber membranes for heads, and which he caused to vibrate by means of a pair of air pumps worked by a crank which rapidly forced air in or sucked it out of the drums. They could be worked in the *same phase*, that is, both bulge out or both cave in at the same instant; or they could be worked in opposite phases, that is, one bulge out while the other caved in. He placed them under water a little ways apart, and made them vibrate in various ways. He

had a third body mounted on a stand and supported by an upright rod of very elastic steel, which was easily swayed by the slightest force. This he placed under the water and moved about from one part of the vessel to another, noting the manner in which it was affected by the currents of the water set up by the vibrations of the drum heads. When a *single* drum vibrated, the effect at a little distance was lines of force radiating from the axis, like the spokes of a wheel, and imitating the magnetic lines seen end-on as shown in fig. 132. When the two drums were placed a little ways apart, in the same line or axis, and vibrated in opposite phases they acted just like a complete magnet, and the lines formed in the water currents took the form of the magnetic lines of force shown in fig. 131. Other experiments showed the same lines which in magnetism are lines of repulsion and which follow the bringing of two poles of the *same name* near each other. This occurred when the two drums were operated in the same phase, both bulging out at the same instant. But the drums instead of repelling, *attract* each other when they vibrate in the same phase. Fig. 147 shows the lines of magnetic force when the north poles of two magnets are brought near each other.

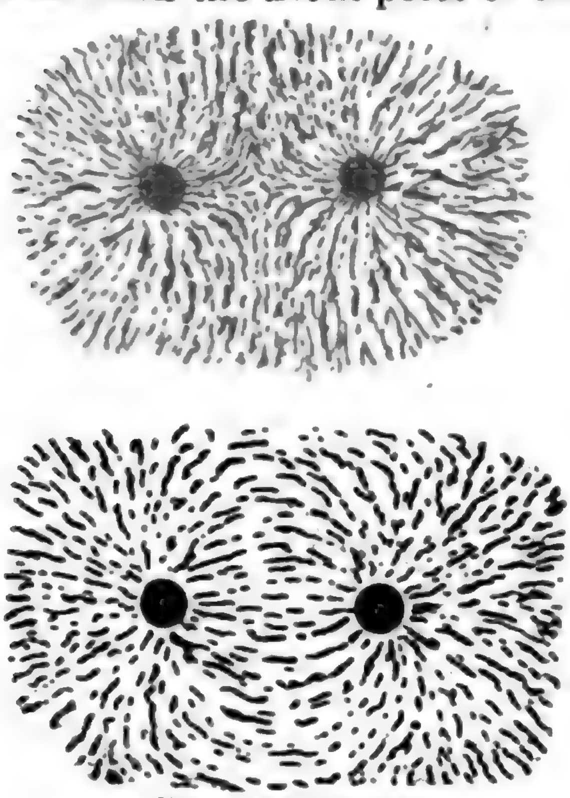


FIG. 147.—Showing lines of *Repulsion* of *Similar Poles* of Magnets.
FIG. 148.—Showing lines of *Attraction* of *Unlike Poles* of magnets.

FIGS. 147 AND 148.

The same happens if both are south poles. The lines of force both rushing out together meet and deflect each other. As they tend to straighten from this compulsory bending, the effect is repulsion. The lines of force between the north pole of one magnet and the south pole of another, as ascertained by the position taken by iron filings sifted between them when they are brought near each other, are shown in fig. 148. These lines are closely imitated by the water currents when the drums are vibrated in opposite phases. In other experiments Prof. Bjerkness showed in the water the same sort of motions as exhibited by electricity in the formation of whirls of force such as shown in figs. 133 and 134. The behavior of two electrical currents when near each other was also imitated; and in short about all the known lines of force emanating from magnetic or electrical agency, can be imitated by water currents when set in motion by vibrating or pulsating bodies. The attraction of the drums for each other takes place when they vibrate in the same phase, and they repel when they vibrate in opposite phases, that is, when one is caving in when the other is bulging out.

Mr. Stroh, following the hint given by these experiments in water, performed a series of similar ones, using air as the fluid to be thrown into motion, and musical reeds in tubes as instruments for communicating regular vibrations to small drum-heads. He got practically the same results as those of Prof. Bjerkness. His vibrating drums attracted each other when vibrating in the same phase, and repelled when vibrating in opposite phases. He found the lines of force by using a small gas jet, which could be moved about the field. When two drums were vibrated in *like* phase, and this flame held between them, it was repelled at right angles from their axis. If such flame be held between the *dissimilar* poles of a powerful electro-magnet, it will be repelled in the same way. Mr. Stroh says that *if* magnetism is due to the vibration of a medium his experiments lead to the conclusion that the rate of such vibration must be identical in all magnets, and that this rate, in fact, constitutes magnetism as distinguished from other electrical phenomena. That magnetism *is* a vibration of a medium like ether, he says, is *strongly favored* by its analogy with vibrating bodies, although the effects appear to be inverse throughout. It is quite obvious that if the magnetic action *is* due to a motion of a medium, the experiments did not precisely imitate it.[1]

Where a current passes from one pole to another it possesses carrying powers. This is well shown in electrotyping, in which currents passed through a solution of sulphate of copper, for example, will pull the copper away from the sulphur and carry it to the negative pole, while the rest of the compound will be carried to the positive pole. A remarkable story was told by the papers not long ago, of a thunderbolt which electro-plated a cat with silver. The cat was sleeping on a sofa, so the story goes, above which hung an old fashioned, silver hilted sword. The lightning traversed the partition on which the sword hung, dissolved the silver which it carried through the air and left neatly coating every hair of the cat, while it continued on its way to the ground. If this be fiction, it is not more remarkable than the truth. The projection of currents must mean the bodily movement of a physical body throwing itself into another body of the same substance at rest. The experiments mentioned above, produced motion in this latter body without taking account of the currents by which the motion is produced, in the case of magnetism and electricity. It was mentioned above that heat may produce or become an electrical current. In like manner an electrical current is, in part, converted into heat, whenever it passes through a metal, but not to the same extent in any two. The following table shows the conducting power of various metals, calling

[1] An account of these instructive researches may be found in Gordon's Electricity and Magnetism.

silver 100, and their resistance to the passage of a current, calling silver 1:

Electrical Conducting Power of Metals.

Name of Metals.	Metals Pure.				Commercial Metals (impure) at the temperature given in last column.		
	Conducting Power.		Specific Resistance.				
	At 0°	At 100°	At 0°	At 100°	Conduct Power.	Sp. Resistance	Cent. °
Silver	100.	71.56	1.0	1.4			
Copper	99.95	70 27	1.0	1.4	77.43	1.3	18.8
Gold	77.96	55.90	1.3	1.8			
Sodium					37.43	2.7	21.7
Aluminum					33.76	3 0	19.5
Zinc	29.02	20.67	3.4	4.8			
Magnesium					25.47	3.9	17.0
Cadmium	23.72	16.77	4.2	6.0			
Calcium					22.14	4.5	16.8
Potassium					20.85	4.8	20.4
Lithium					19.00	5.3	20.0
Cobalt	17.22		5.8				
Iron	16.81		5.9		14.44	6.9	20.4
Nickel	13.11		7.6				
Palladium					12.64	7.9	17.2
Tin	12.36	8.67	8.1	11.5			
Platinum					10 .53	9.5	20.7
Thallium	9.16		10.9				
Lead	8.32	5.86	12.0	17.1			
Strontium					6.71	14.9	20.5
Arsenic	4.76	3.33	21.0	30.0			
Antimony	4 62	3.26	21.6	30.7			
Mercury					1.63	61.4	22.8
Bismuth	1.24	0.88	80 3	113.9			
Tellurium					0.00077	129.8	19.6
Red Phosphorus.					0.0000123	81.300 000	24.0

The conducting power is decreased in all in the same proportion by increase of heat. The *resistance* of any conductor to the passage of any body through it tends to arrest part of the motion of that body so that it comes out at a slower rate and in diminished volume. This loss of motion in the passage of the body reappears in the shape of heat. Thus, electricity being convertible into heat, it is proved to be a motion of some *thing* or *substance.* It has been shown that the speed of induction when allowance is made for the resistance of the conductor is practically the same as that of light, from which it has been concluded by some physicists that the two are different sorts of motion of one and the same substance, *Ether*.

The units of measurement for electricity and magnetism are units of *distance, weight* and *time*, as follows: the *Centimetre*, C., = nearly .4 inches; the Gram, G., = 15 and 4-10 grains; the Second, S. These are called the C, G, S units. A force which acts on one gram for one second of time, and imparts to it a velocity of one centimeter per second, is the unit of force, and is called one *Dyne*. It takes about 455 thousand *dynes* to equal a pound Avoirdupois. The *unit* of *magnetism*, or *magnet pole* of *unit* force, is one that when placed (in air) one centimeter from a similar pole of equal strength, it repels it with the force of one *dyne*. The amount of *work* required to move a body one centimeter against the force of one dyne, is called an *erg;* and it is the *unit of work*.

The measure of the *quantity* of *electricity* is the same as that of magnetism, that is, it is the quantity of electricity which, at a distance of one centimeter, will repel an equal quantity with the force of one dyne. As this unit is too big, the *practical* unit is assumed at one-tenth of this absolute unit, and is called the *Coulomb*. The absolute unit of *current* is one of such strength that when one centimetre length of its circuit is bent into an arc of one centimeter radius, the current in it exerts a force of one dyne on a unit mag-

net pole placed at the center. This absolute unit is too large, and in practice is difficult to be realized. So the practical unit of current, which is called the *ampere*, is fixed at *one-tenth* of the absolute unit; and the measurement is made by means of the *standard galvanometer*. This instrument is essentially a magnetic needle suspended in the middle of a circular coil of wire, the coil to be set upon edge so that its plane stands parallel with the magnetic meridian. Its action upon the needle when a current is passed through the coil, tends to cause the needle to take a position at right angles to the coil.

The magnetism of the earth tends to keep the needle in the Earth's magnetic meridian, while the current of electricity through the coil tends to deflect the needle from the meridian. The *force* of the earth's magnetism varies in different localities, so that the ampere-meter must be different in different localities to suit. The more intense the magnetic current of the earth is, the closer must the current through the galvanometer be to the needle, in order to deflect it to the same extent. Hence, where the earth-current is weak the diameter of the coil in the instrument is made large. Thus, at London the intensity of the earth current is .180, and the diameter of the coil is 6.87 inches. At New Orleans the earth current is .280, and coil 4.42 inches. When the current through this is just strong enough to deflect the needle 45° its force is that of one ampere. The tangent of 45° is the same as the radius. The natural tangents of other degrees of deflection in the ampere-meter, indicate amperes directly—thus a deflection of 63°.30 = 2 amperes, 71°.35 = 3 amperes, 76° = 4 amperes, 78°.45 = 5, &c. "A current of one ampere will cause the deposit in one hour 1.174 grams, or 18.116 grains, of copper in a copper electrolytic cell. It will in one hour deposit 4.024 grams, or 62.52 grains, of silver in a silver cell." (Thompson.)

As stated above, every field of magnetic or electric force is such by virtue of *lines* of force which are supposed to traverse it, as shown by the manner in which iron filings are arranged by a magnet. For the sake of convenience it is assumed that each line represents the force of one *dyne*, and that the intensity of the field depends on the number of these lines in a given area or section, say one centimeter. When the magnetic pull on a unit magnet pole is, say 40 dynes, then, it is said there are 40 lines of force within a cross section of a square centimeter.

Electromotive force depends upon the number of magnetic lines of force that are "cut" by a conductor moving in a field of magnetic force. (See fig. 136.) The dyne unit of magnetic force is an obvious measure of Electromotive force, therefore, and would be adopted if it were not far too small for practical work. What has been adopted is a unit composed of one hundred millions of the aforesaid absolute units. This great unit of Electromagnetic force is called a *Volt*. A definition of one volt is, therefore, the electromotive force generated by a conductor cutting across a hundred million magnetic lines per second. This is measured in practice by any cell of constant known force. A Daniell's cell has a force of about 1 1-10 volts. A cell invented by Latimer Clark, is very constant at about 1 4-10 volts. The *Ohm*, or unit electrical resistance, is made necessary by the fact of resistance to the passage of a current in every conductor however good. The actual available current for work is reduced by the resistance of the conductor, and is the quotient resulting from dividing the electromotive force by the resistance. The Ohm, or unit of resistance, is fixed at one thousand millions of C. G. S units. 1 volt divided by 1 ohm is equal to 1 ampere. An electrical *Condenser* is an apparatus for holding electricity in a potential condition. A Leyden jar is a condenser. The capacity of a condenser is measured by an absolute unit called a *Farad*. A condenser which holds one Coulomb at a potential of one Volt, has a capacity of one Farad. This is too large a measure for practical use, and so the little farad, or *Microfarad*, is used. It takes a million Microfarads to make one Farad.

The amount of work done in one second by an electrical machine is expressed by a unit called a *Watt*, which is the same as one *volt* multiplied by one *ampere*. Calculation shows that 746 watts equal one horse-power. If a certain arc lamp has a pressure or potential of 57 volts between the lamp terminals, and the current is ten and a half amperes, the power expended is 598 and a half watts, or about eight-tenths of a horse-power. Another "unit" is one of *1,000 watts*, equal to one and a third horse-power, and is used to designate the power of dynamos. A machine having the power of 8,000 watts is an eight "unit" machine.

CHAPTER XXXVII.

CRYSTALLIZATION.

Since we have got a habit of talking of the *mineral kingdom* and of *organic kingdoms,* we are apt, inadvertently, to get a half impression that these are independent departments of nature in which the materials used and the laws governing their movements and arrangements are different and independent. It is our first duty to rid ourselves of this false impression, and to come to a realization of the fact that nature is only *one.* We may call it all a *mineral kingdom* if we choose; in which case we are to consider every organic body as a lot of minerals arranged in a particular *form,* and therefore liable to a particular set of reactions. Or we may call it all an *organic kingdom,* in which case the so-called minerals become organic bodies of simple constitution.

From very much that has gone before, we have reason to conclude that organisms are built up, altered and amended, moved and operated by forces chiefly external to themselves. If we inquire among the minerals, at the first glimpse, we will be apt to suppose that they are more independent of their surroundings. They seem to have their likes and dislikes, their affinity for this, and their indifference to that. Their affinities appear at first to be absolute and ultimate, belonging to themselves and not to be questioned; theirs, just because they *are,* and always have been. But investigation shows that the so-called elementary bodies are by no means exempt from the influence of energies external to themselves. Even their very affinities are largely conditional—in fact, I think we may say wholly conditional on the action upon them of external energy in the shape of heat, light, electricity, &c. We have seen that the effect of various dynamic agencies upon bodies organized into machines depends entirely on the form and make-up of the machines themselves. But *every* body is organized into a machine. The atom, which is conceived by the chemist to be the smallest particle of any element, is never found except in combination with others. Therefore it is always a part of a machine. There is nothing but a series of machines from atoms to elephants. A molecule, which is the smallest quantity of a compound that can exist by itself, is composed of at least two atoms, and may be composed of a great many. So that even a molecule is a machine whose reaction against any sort of energy depends upon its structure; that is, the number and shape of its atoms and the manner in which they are attached to each other. Since two bodies may be composed of the same kind of atoms in the same number, and yet be radically different by reason of the manner in which the component atoms are stuck together, it follows that *form* alone may

give rise to a divergence of chemical and physical reactions; and the logical sequence of this is, that traced to ultimate conditions, the *only* difference between atoms may consist in difference of *form*. We shall find many facts which point to such conclusion. If that is the case, it will follow further that all their supposed properties, affections, affinities, &c., are merely diverted forms of external energy, and come into existence as such, or go out, according to the manner in which they are assailed by external energy. This is true of the great artificial machines, as everyone will admit without argument—and it is true of the great organisms, as can be proved, if need be. What is true of the great may be equally true of the small. That the influence of form is paramount, in some cases, at least, is proved by the facts of *allotropism* and *isomerism*. The meaning of the first term is—"of another habit," and it is applied in the case of those elementary bodies which show themselves in more than one form. Some examples of allotropism will be mentioned. Oxygen has three habits of existence; viz., as oxygen, ozone, and antozone. Ozone is once and a half as heavy as oxygen, and has most of the properties of oxygen intensified. It has an odor like sulphur. A molecule of common oxygen has two atoms, while a molecule of ozone has three. Ozone is formed from oxygen by *heat*, by *light*, and by *electricity*, and is often detected in the air after a thunder-storm, by its odor. At a temperature of 290° it is reconverted into oxygen. *Antozone* is formed whenever ozone is, and is changed to oxygen by being heated. It is a great agent in the formation of fogs and clouds with water. Thus the difference between these three is very considerable, and they have quite different affinities, yet are interconvertible into one another; in fact, are three habits of the same thing—made different by different external conditions.

Phosphorus is an elementary body which without losing its name may occur in two different allotropic states. In the ordinary state it is called *Alpha* Phosphorus. It is colorless and it forms into twelve-sided crys-

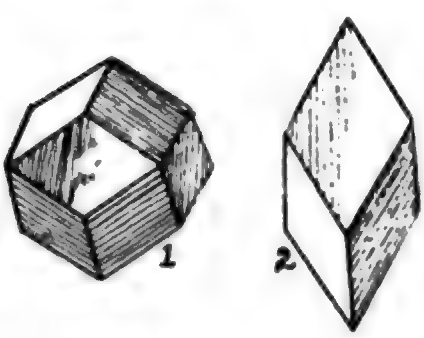


FIG. 149.
FIG. 149.—*Phosphorus Crystals.*
1.—*Alpha* Phosphorus.
2.—*Beta* Phosphorus.

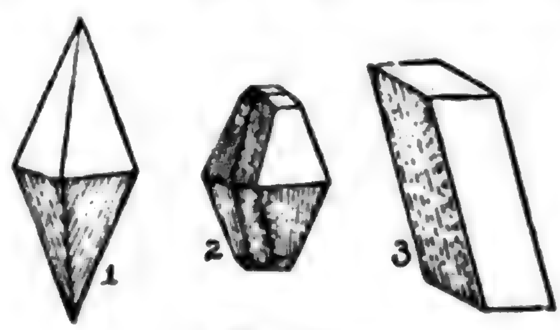


FIG. 150.

FIG. 150.—*Crystals* of *Sulphur.*
1, 2.—*Alpha* sulphur.
3.—*Beta* sulphur.

tals, fig. 149, 1. Its specific gravity is 1.83, it melts at 44° and boils at 290°. In the air at 50° it takes fire. It is violent poison. *Heat* of 250°

in a *particular gas* converts it into the second variety called *beta* phosphorus. This is red and forms into acute rhombohedral crystals of a specific gravity of 2.34. It does not take fire in the air till heated to 260° and it is not poisonous. It melts at 260° and is then reconverted into the alpha variety.

Sulphur is an element which exists in *three* distinct forms. In the first variety, called *alpha* sulphur, its crystals are forms of orthorhombic octahedrons like numbers 1 and 2, fig. 150. Its specific gravity in this form is 2.05. The *beta* variety is in monoclinic crystals like 3, fig. 150. The specific gravity of this is 1.95. The first variety is soluble in carbon di-sulphide, but the second is not. The second tends with the aid of heat to pass into the first. The third variety or *gamma* sulphur is formed into a waxy, sticky amorphous mass by pouring melted sulphur at 250° temperature into cold water. This variety has a specific gravity of 1.95 and like the second is insoluble in carbon disulphide. The third sort passes slowly into the first. But it passes quickly if heated to 100° and in doing so becomes ten degrees hotter. Experiments with sulphur gas show that its molecule at a temperature of 500° contains *six* atoms while at 1000° it contains but *two*.

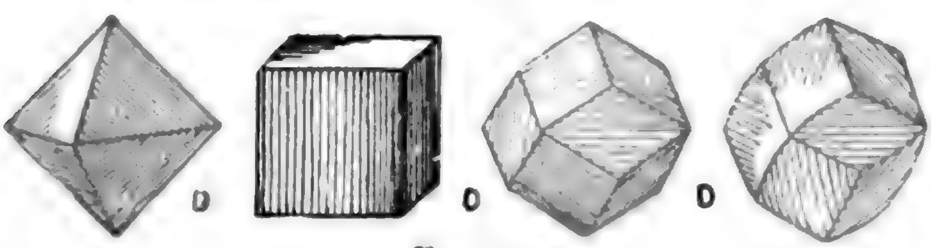


FIG. 151.

Different Crystalline forms of Diamond.

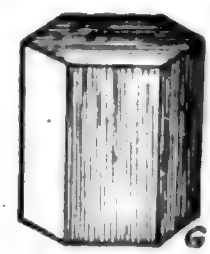


FIG. 152.

Graphite Crystal.

Carbon has three allotropic states: *diamond*, *plumbago* or *graphite*, and *charcoal*, *lamp-black*, &c. It is well known that in any of its solid states, as charcoal, &c., carbon does not unite with oxygen at ordinary temperatures, and is in fact one of the least oxydizable substances in nature. It is known to have remained unchanged for 2,000 years. But when heated it rapidly unites with oxygen forming carbonic dioxide.

Silicon, which next to oxygen is the most abundant substance on earth, exists in three allotropic states much like those of carbon; that is, it is diamond-like, graphitoidal, or amorphous. The first variety is in the form of regular octahedral metallic-like crystals with specific gravity of 2.49. The second variety crystallizes in bright hexagonal plates. At a very high temperature it passes into the diamond form. The amorphous variety is a brown powder. At about 2000° temperature it melts; and if mixed with salt at a heat sufficient to vaporize the latter, it passes into the graphitoidal sort.

Selenium has two or three allotropic states. The first, *alpha*, is a dark, grayish solid, *not* soluble in carbon di-sulphide; with specific

gravity of 4.8. The second, *beta*, is dark, reddish-brown in monoclinic crystals of a specific gravity of 4.5, and soluble in carbon di-sulphide. There is also a third, amorphous, kind with specific gravity of about 4.3. At a temperature of 100° the *beta* variety changes into the *alpha* sort giving out heat in doing so.

Boron also exists in two states. In one it is a fine amorphous, greenish powder and easily takes fire. A hot summer sun will touch it off. The other sort crystallizes like diamonds and is nearly as hard, is transparent and sometimes colorless. It is difficult to burn this variety even in oxygen gas.

Antimony. This metal is dimorphous; that is, it crystallizes in two forms of crystals, rhombohedrons and octahedrons. It is bluish-white with specific gravity of 6.7. But it is also obtainable in an amorphous condition by means of *electricity*, in which form its specific gravity is 5.8. If this form is gently *heated* or *struck*, it passes into the crystalline form, giving out great heat in doing so.

Chlorine is an elementary gas which exists in two states; one *active*, the other *passive.* The activity depends upon *light.* When it is prepared in darkness it is of a sluggish nature. It may be mixed with hydrogen, and if kept in darkness the two will remain indifferent to one another. But if the mixture be exposed to sunlight they will at once unite with a great explosion.

Isomerism. This word means having equal or similar parts, and it is used to designate those bodies which are composed of the same elements in equal quantities, but which are nevertheless possessed of different properties. It amounts to the same thing as *allotropism*, but the latter word is generally applied to elementary bodies, while isomerism is applied to compound bodies. There are a great many isomeric compounds, and as mentioned before, the differences between two of the same name is a difference in the *form* of their molecules, or in the way in which they are put together. The dextroses and levuloses mentioned in chapters 27 and 28 are isomeric compounds. Woody fibre and gum are isomeric with starch, all three containing carbon, hydrogen and oxygen in the same proportions. There are a great many crystalline bodies whose molecules are put together in a spiral twist, so that light, in passing through them, has to *bore* through like an augur. And as before mentioned, it is obliged to turn to the left in some bodies and to the right in others. There are two sorts of Tartaric acid; a solution of one turns the beam of light to the left, the other to the right. An examination of the crystals of this compound shows them to be alike in every respect, except that they are rights and lefts, that is, if one be held up before a mirror, its image in the glass will represent the other. The chemical difference between these two is slight; but it is remarkable that the two may be made to

combine with each other, and thus form a new body called *racemic* acid. (Cooke's Chem.) The salts of sesquioxide of chromium, as well as the oxide itself, occur in two isomeric conditions, one known as the green and the other the violet modification. The compounds of the latter usually crystallize readily, while the green compounds do not. If a solution of the violet salt is *heated* nearly to the boiling point it is apt to pass into the green sort and become un-crystallizable. Calcic Carbonate is formed into two very distinct and different forms of crystals, one of which is calcite and the other aragonite; which differ in density, hardness and other qualities, but are the same chemically. In like manner there are three natural forms of Titanic Oxide answering to the three minerals, rutile, brookite and octahedrite.

Ethylic Formate is very different from Methylic Acetate, but they are composed of the same $C_3 H_6 O_2$.

Arsenious Acid. $AS_2 O_3$ exists in an amorphous glassy state, but upon contact with air it becomes changed into minute octahedral crystals, opaque and porcelain-like. It also takes a third state, forming in right rhombic prisms. The amorphous and crystalline varieties differ in chemical as well as physical properties, but are absolutely identical as to kinds and numbers of component atoms.

The following essences are composed of exactly the same atoms and expressed by the same formula, $C_{10} H_{16}$; viz., Lemon, Bergamot, Cubebs, Neroli, Juniper, Lavender, Gilliflower, Pepper.

$C_4 H_8 O_2$ forms *Butyric Acid*, which is of rank odor, boils at 156° C. and does not easily inflame. $C_4 H_8 O_2$ also forms *Acetic Ether*, which is a clear liquid with a pleasant fruity smell, highly volatile, boiling at 74° C., and inflaming with the greatest ease.

One variety of isomerism is called *polymerism*, by which it is meant that a body possesses the same sort of atoms as another body and in the same proportion, but that the absolute number of atoms is multiplied two or more times. For example, butyric acid is polymeric with respect to oxide of ethylene which has a formula of $C_2 H_4 O$. This is just half the molecule of butyric acid. Acetic ether is also said to be a polymer of aldehyde, which has the same molecule as ethylene. Then there is another compound body called paraldehyde whose molecule is $C_6 H_{12} O_3$, which is three molecules of aldehyde condensed into one. Compounds when left to themselves often undergo transformations into other substances, and these are frequently multiples of the first, the molecules either doubling, trebling, or halving, &c. Cyanimide, $C N^3 H^2$, at 150° temperature centigrade is converted into cyanuramide, $C_3 N_6 H_6$, a molecule multiplied by three. Anhydrous sulphuric acid, $S O_3$, is a white substance composed of glistening crystalline fibres and is something like asbestos. There are two varieties of it which pass into each other, the

difference between them relating to the temperature at which they can be melted ; one variety melting at 18°, the other at 100°. The first when left to itself changes slowly into the second, while the second may be converted into the first by distillation. Many such examples could be cited. Again it is remarkable what changes in the constitutions of compound bodies accompany small variations in the atomic structure.

The composition of the petroleums is as follows :

Methylic Hydride		$C\ H_4$	Gas.	
Ethylic	"	$C_2\ H_6$	"	
Prophylic	"	$C_3\ H_8$	"	
Butylic	"	$C_4\ H_{10}$	Boils at	32°
Amylic	" Naptha	$C_5\ H_{12}$	"	86°
Hexylic	" " and Kerosene,	$C_6\ H_{14}$	"	142°
Heptylic	" Kerosene.	$C_7\ H_{16}$	"	194°
Octylic	"	$C_8\ H_{18}$	"	247°
Nonylic	"	$C_9\ H_{20}$	"	303°

The common difference of the progression is $C\ H_2$. (Eight essences named above, each $C_{10}\ H_{16}$.)

Composition of Alcohols :

Methylic alcohol,	Wood spirit	$C\ H_4\ O.$
Ethylic "	Common	$C_2\ H_6\ O.$
Prophylic "		$C_3\ H_8\ O.$
Butylic "		$C_4\ H_{10}\ O.$
Amylic "	Fusel oil	$C_5\ H_{12}\ O.$
Hexylic "		$C_6\ H_{14}\ O.$
Heptylic "		$C_7\ H_{16}\ O.$
Octylic "		$C_8\ H_{18}\ O.$

The common difference of the progression is $C\ H_2$.

A glance at the foregoing shows how nearly alike a great many very different things are. Add to kerosene one atom of oxygen and we have a powerful alcohol. Simply rearrange the atoms of one essence and we have another. What could we have antecedently suspected there is in common between the acid of rancid butter and acetic ether? Yet they are composed of the same atoms in the same proportions. Eliot and Storer say "that the widest diversity of properties may coexist with absolute identity of ultimate chemical constitution. Two allotropic states of the same element not infrequently present more striking difference than elements recognized as distinct; and among the numerous compounds of carbon with which organic chemistry deals, there are many isomeric compounds which are so entirely dissimilar as to lead almost irresistibly to the belief that it is of as much consequence *how* the atoms of a compound are arranged as to *what kind* of atoms they are." It is important to observe to how great an extent the allotropic and

isomeric states of bodies are due to the agency of external energies. A change from one state to another is always accompanied by a demonstration of energy in some form—heat, light, electricity, a blow, or even a stirring with a stick. In passing from an amorphous to a crystalline state, it generally appears that heat is given out. Thus sulphur gives up 10° of heat in making this transfer. Antimony gives out great heat in doing it. When arsenious acid of the amorphous glassy sort changes into the opaque variety heat is given out, and if it is done rapidly a flash of light goes with it. From this it would appear that the amorphous condition is a position of potential energy, heat being used to bring it about, which heat reappears when the body is let down again.

There are two conditions in which different compound bodies appear, called *colloid* and *crystalloid*. Bodies which, when put into water, rapidly diffuse through it like sugar or salt, and are capable of crystallizing, are called crystalloids, while those which are not capable of crystallizing readily, or of diffusing through water, are colloids. The colloids are insipid or tasteless, and are apt to form into jellies by combining with water. The word means *like glue*, and gelatine is a type of this class of bodies. Among the colloids are silicic acid ($Si\,O_2$), alumina ($Al_2\,O_3$), starch, gums, caramel, albumen, tannin, gelatine, and the extractive matters of various animal and vegetable tissues. Crystalloids are separated from colloids by dialysis, which is a sort of sifting process through a tray made of parchment paper, which is itself an insoluble colloid. The tray is laid upon a vessel of water and the solution to be dialysed is poured on it. The crystalloid passes through the membrane and diffuses in the water below, leaving the more sluggish and inert colloid behind. There is no definite boundary between colloids and crystalloids, some crystalloid bodies being far more diffusible than others. But a very significant fact is that a great many bodies pass from a colloid to a crystalloid state, and vice versa. Thus alumina, ferric oxide, chromic oxide, silicic acid, stannic, metastannic, titanic, molybdic and tungstic acids, may exist in either condition; although they are commonly met with as crystalloids.

It is said that the red globules of blood are often transformed into oblique rhombic crystals, and chlorophyl has been found in a crystalline state by M. Trecul. Myeline also has been known to undergo the same sort of change. According to Dr. Marcet, the blood contains phosphoric anhydride and iron in a perfect colloid state, not diffusible. Dr. Graham is the highest authority on this subject, and both he and Dr. Marcet assert that there is a constant change in colloidal compounds back to crystalloids, and from crystalloids to colloids. The difference between the two appears to depend upon dynamical agencies external to themselves; which, by causing a polymeric condensation of the mole-

cules of a crystalloid, forms it into a colloid. Prof. Graham is inclined to think that the colloid molecule is constituted by the grouping together of a number of smaller crystalloid molecules, and that the basis of colloidality consists in this composite character of the molecule. This condensation of molecules is only accomplished by some form of energy, and generally this energy is given up in the shape of heat, when the body returns to the crystalloid state. The importance of the relationship between these two states of bodies, consists in the fact that vegetable and animal organisms are made up of combinations of the two. The mass of the tissues are colloidal, but these colloids grade in the same tissue into materials more or less crystalloid. The fact appears to be that the materials in the solutions from which nourishment is drawn, are, in part, crystalloid and diffusible, and when incorporated into the tissues are promoted to the colloidal state. Their initial diffusibility is a useful and probably an essential quality, because by it they are able to pass through colloidal membranes and tissues so as to reach their destinations in the body. Colloids are not able to pass through other colloids. The reason is found in the comparatively large size of their molecules; the small crystalline molecule getting through a hole that stops its big brother, the colloid molecule. The difference between the two, then, is physical, and it allows a variety of physical reactions. A certain degree of temperature is required in some cases to retain a constituent in solution, and when the temperature is either raised or lowered from this normal degree, the constituent separates from the solution. "Thus, when a hot saturated solution of alum or nitre is allowed to cool, some of the salts crystallize out of the solution; when heat is applied to a solution of lime, some of it becomes precipitated; whilst when either heat or cold is applied to a solution of sodic sulphate, already at a temperature of 33° C., some of this salt separates from the state of solution."

Many bodies, both simple and compound, crystallize in forms which belong to two or three different systems of crystallization, or to different subdivisions of the same system. Such bodies are called dimorphous and trimorphous, and they differ in their specific gravity, hardness, color and other properties. The chief cause of these different modes of crystallization lies in different states of temperature, but sometimes it depends on the components of the solution from which the crystallizing body is separated; thus, arsenious anhydride crystallizes from water or hydrochloric acid in regular octahedrons, but from alkaline solutions in trimetric prisms. A hot solution of saltpetre yields, when slightly cooled, nothing but prismatic crystals, but at 10° C. prismatic and rhombohedral crystals appear together. Again, if a solution of carbonate of calcium in water containing carbonic acid be left to evaporate at the or-

dinary temperature nothing is obtained but calc-spar in microscopical, and for the most part truncated, primitive rhombohedrons; if, on the contrary, the solution be evaporated over the water bath, arragonite is obtained in small six-sided prisms, mixed with a few crystals of calc-spar, because the temperature of the solution is lower at first than it afterwards becomes. (Bastian.) The polar tensions of the molecules are, without doubt, due to the transmutation of heat into polar energy, and it appears that different phases of polar energy follow different conditions of temperature; doubtless due to the changing forms of the molecules and the intermolecular spaces. The changes which take place in these transmutations are often spoken of as "spontaneous." This is because so slight a demonstration of force is required that it is not conspicuous. Watts says "Sometimes an amorphous solid, that is to say one which has no definite structure, either crystalline or organized, passes spontaneously into the crystalline state without previous liquefaction; but generally speaking it is in the passage of a body from the liquid or gaseous to the solid state, that the regular and symmetrical arrangement of the molecules takes place, which constitutes crystallization. The vapors of many substances, when they come in contact with cold surfaces, pass at once to the state of crystalline solids; e. g., sulphur, iodine, benzoic acid, arsenious acid, camphor, &c. It is, however, in the transition from the liquid to the solid state that crystallization most frequently takes place. If the body has been brought into the liquid state by the action of *heat* alone, it may be made to crystallize by cooling, as bismuth and sulphur, for example." Again, "The more slowly the liquified body is brought back to the solid state, and the more the liquid is kept at rest, the smaller the number and the greater the size and regularity of the crystals; but if the solvent be cooled or separated quickly, the crystals are numerous but small and ill defined. In the former case, the particles of the solidifying body have time to unite themselves regularly with those which separate first from the fluid and form nuclei of crystallization. If, on the contrary, the crystallization takes place rapidly, a great number of particles solidify at the same time, each forming a nucleus to which other portions attach themselves, and thus we obtain a number of crystals irregularly formed and interlacing each other in all directions." The transition between small, ill-formed crystals and mere amorphous granules is easy to be accounted for by a still greater rapidity of separation.[1]

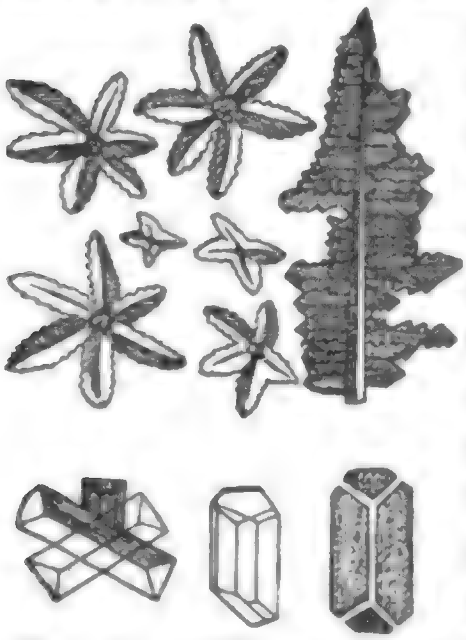


FIG. 153.—*Different Crystalline forms assumed by Ammonio-Magnesic Phosphate.*

[1] Watts' Chemical Dictionary.

The polarity of the first molecules forming a nucleus of crystallization, determines their position with reference to each other, and as a crystal is built up, the shape of it tends to constantly remain the same as the initial nucleus of molecules. If, in a solution of nitre and sulphate of soda, a crystal of *nitre* be dropped, all the dissolved nitre crystallizes, the sulphate remaining in solution. But if a crystal of *sulphate* of *soda* be dropped into the solution, instead of the crystal of nitre, all the sulphate of soda will become crystallized, leaving the nitre still dissolved.

"If a portion of a crystal be broken off or filed or dissolved away, and if then the mutilated crystal be replaced in a solution of the same salt or of an isomorphous one, the lost part will be replaced, the crystal will be enlarged, new crystallized matter will be formed on every surface; but the quantity formed on the injured part will be greater than that formed at any other part and repair will be more active than mere growth till the proper form of the crystal is regained. Then when the repair is complete, growth alone will go on and each part of the crystal if it remain in the same solution will increase in due proportion with the rest." A crystal once formed in a solution (or at least every face of

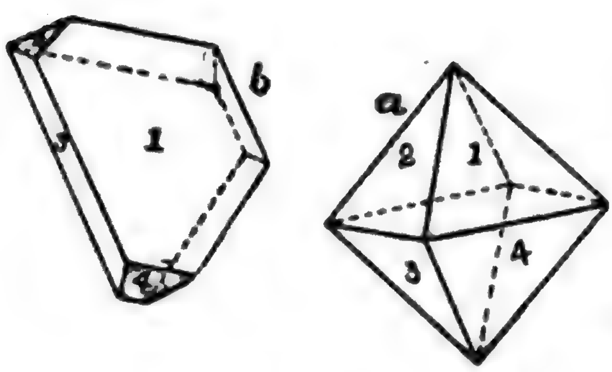


FIG. 154.

FIG. 154.—*Alum Crystals.*
a.—Ideal form obtained when the crystal is constantly turned during its growth so as to give all sides an equal chance.
b.—Distorted by growing in contact with the side of the vessel.

any set of its faces) would continue to grow equally by the deposit of the same amount of material on every side But in reality it rarely does, because the formation of the crystal changes the specific gravity of the solution and that changes the currents in the crystal, so that the deposits on the different faces become unequal. This is called distortion, and it is also brought about by the crystal becoming attached to another crystal or to the side of the vessel. "When new material is very quickly presented to a growing crystal it is often noticed that the acuter solid angles grow very rapidly, shooting out long needle-like points, and often other acicular points will start from along the first, and thus fern-like forms are produced; all such growths are called *crystalline skeletons*; when the rate of deposit becomes less, the needles almost cease to grow in the direction of their length, but increase continually in breadth and thickness until they touch each other and the crystal returns to its original appearance, though often containing a great number of cavities filled with the mother-liquor, and these cavities will take the general form of

the crystal. Figure 155 shows dendritic or tree-like crystallizations, due to polar action in the placing of molecules. The dendrite on the left is a natural formation from Painted Rock, Montana. The rock is full of the slightest of checks or cracks made by unequal settling or tilting of the strata, and into these, water holding minerals in solution has infiltrated and the particles of the minerals have become arranged according to their polarities into the most beautiful forms. The silver trees on the right of the fig. are formed by artificial electric currents in the process of electrolysis. The same effects are seen in the frost foliage formed on our windows in winter, and in the formation of leaves on vegetation in summer.

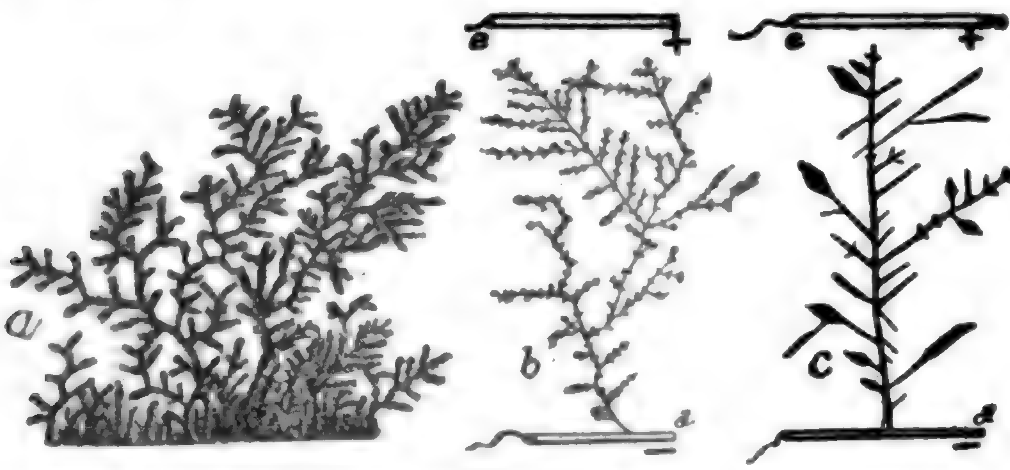


FIG. 155.

FIG. 155.—*Metallic Crystallization.*
a.—*Natural Dendrite* from rocks near Painted Rock station, Montana.
b.—*Silver tree* formed in a weak solution of silver nitrate by means of an electric current (with platinum poles).
c.—*Same* formed in a solution a little stronger.
The "trees" start at the *negative* pole of the battery (*d*) and grow toward the positive (*e*). Tin trees can be raised the same way from a solution of tin chloride; and lead trees from a solution of lead acetate. Crystalline dendritic forms are also produced from chloride of ammonium, &c.

"A solution saturated at a high temperature may, under certain circumstances, be cooled down several degrees without depositing crystals, but the introduction of a crystal of the substance causes the whole to solidify instantly into a crystalline mass. The phenomenon is easily exhibited with Glauber's-salt." That this difference is only one of degree, however, is shown by the fact that crystallization will take place "spontaneously" if the temperature be still further lowered. Crystals formed at one particular temperature and then exposed to another temperature at which crystals of another kind are produced, often lose their transparency and without alteration of external form *become changed* into an aggregate of small crystals of the latter kind. Examples of this alteration of structure are afforded by sulphur, carbonate of calcium, mercuric iodide, and many other bodies." Mercuric iodide when sublimated at a gentle heat forms in scarlet tables belonging to the dimetric system. But at a higher temperature its sublimate is in yellow rhombic tables of the monoclinic system. The red crystals turn yellow when heated and resume their red tint on cooling. The yellow crystals retain their color

when cool, but on the slightest rubbing or stirring with a pointed instrument the part which is touched turns scarlet and this change of color extends with a slight motion as if the mass were alive throughout the whole group of crystals as far as they adhere together." (Watts.) There is a striking analogy in this action with that of fermentation, especially when the latter is carried on through the agency of the insoluble ferments, which are very rapid in their effects. A change of temperature

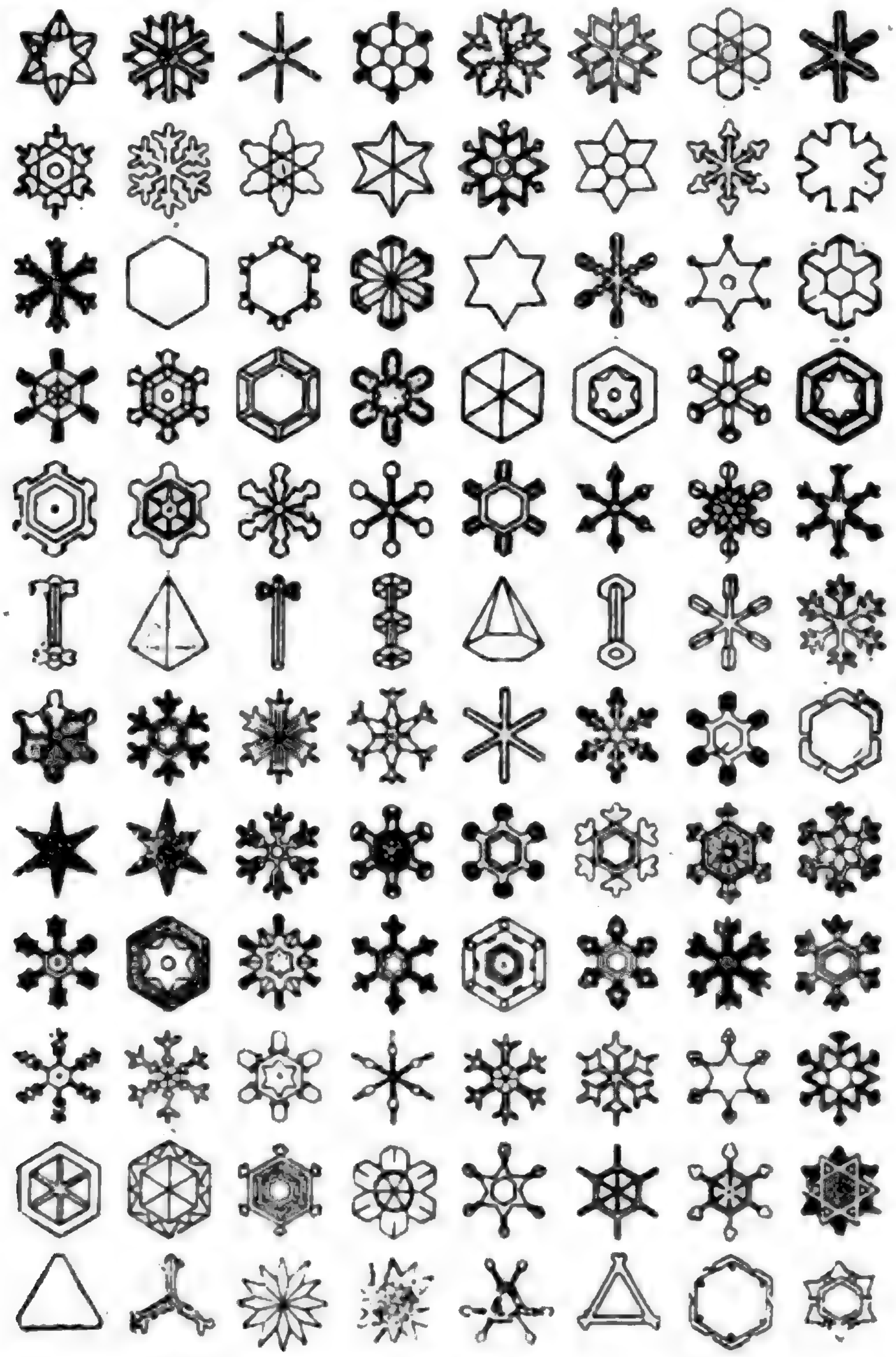


FIG. 156.

FIG. 156.—*Different forms of snow crystals.*

occurring during the formation of a crystal is evidently competent to disturb its symmetry and often does it, and as an example above given shows is even able to rebuild work on a new plan when once completed. Crystals of Snow, as shown by fig. 156, take a great number of forms, although it is said that only one form usually occurs in any one storm, presumably on condition that the electrical status remains the same. A crystal must be recognized as an organism, and a live one at that, at

least during growth. It is not so easy as it might appear to find a di-viding line between crystals and vegetable and animal organisms. Both of them as a general thing reach a limit of growth, which arises as a direct consequence of growth. There are apparent exceptions to this, but not real ones. A tree may continue to grow for a thousand years and it does not stop as long as it lives. Some reptiles grow as long as they live. There does not seem to be any reason why such a crystal as a hail-stone might not continue growing as long as material is supplied, since the crystals when regular, as in fig. 157, are placed side by side. But there is always a limit. If a tree planted at the beginning of the Eocene Period had possessed a monopoly of all the carbon dioxide on earth, it would by this time have had all the carbon consolidated in its tissues, and it would have to stop growing for want of material, just as a crystal stops when all the material in the bath is exhausted. But

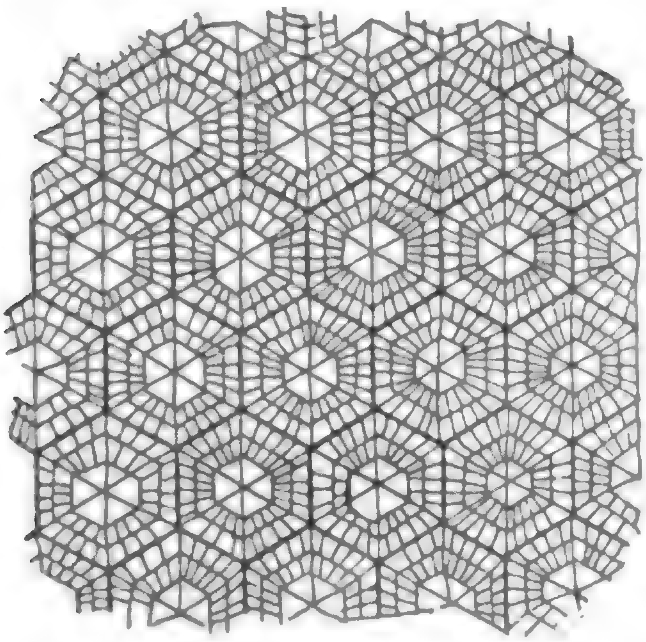


FIG. 157.—Section through a *Hail-stone* showing its crystalline structure.

aside from this there are other limiting causes. Growth is caused by the deposit of materials in a definite way by polar energies. When a certain amount is deposited, the crystal gets into shape which changes its polarity, or some other condition becomes a bar to further growth. A hail-stone might get to be as big as an iceberg if it could remain in the air long enough. An animal or vegetable organism is *wasted* as well as built up by the energies which operate it, and when the amount wasted is equal to that used in building up there is a cessation of growth. Even in the matter of reproduction the principal is the same in crystal and animal. If you wish to start the growth of a crystal, drop into an appropriate solution a small fragment of crystal as a *seed*, and the adult crystal grows from that as a nucleus. As we have seen in chap. 33, it is a fragment of the parent that becomes the nucleus of the offspring. The crystal appears to have the advantage in reproduction for it may start in a solution in which no "germ" of a crystal can be detected. But the germ is there all the same, for every molecule, infinitesimal as it is, has its definite form and polarity, and by the polar currents set up in the solution is impelled toward neighboring molecules, and their aggregation constitutes the finished body. An animal must be regarded as an aggregation of a number of different sorts of crystals, or the *colloid products* of crystals. Each of these different sorts must have its nucleus

before polar action can begin to reproduce it. Suppose that every sort or species of tissue in the body is represented in the reproductive nucleus or seed by one molecule or group of molecules; when the whole aggregation is immersed in a solution containing materials for all, they must select and assimilate these materials in the construction of a form to correspond with their constitution and polarities. So that the difference between a crystal and a so-called vital organism is one chiefly of degree, not of principle.

CHAPTER XXXVIII.

POLARITY IN ORGANIC ELEMENTS.

The molecules that go to make up the various tissues of the organized body, all possess form and polarity peculiar to themselves, and the tissue to which each molecule belongs occupies a relationship to it similar to that occupied by a mineral crystal to its component molecules. The tendency of the tissue is, like a crystal, to preserve its shape when finally formed, and when some of its molecules are disrupted the polar attractions of the remaining molecules are exerted to win similar particles from the dissolved organic molecules of the blood to fill up the void and make the repair. Thus in a healing ulcer the new skin grows from the edges of the sore in connection with the epidermal cells already there. In order to hasten the healing process, surgeons sometimes transfer a small piece of epidermis from some healthy part of the body to the middle of the sore to be healed, and the new skin then grows from the edges of this, and it is observed that, as it approaches the margin of the sore, it stimulates the production of new tissue there if sluggish as it sometimes is.

It is well known that minute fragments cut from a hydra or from a medusa, when placed in suitable situations, are capable of developing into perfect organisms similar to those from which they had been derived, just as a mere fragment of a crystal thrown into an almost supersaturated solution of the same salt will lead to the formation of a perfect crystal. No less than forty perfect polypes have been produced from the mince meat of a single one. We are told, moreover, by Dr. Hooker, that there is a species of Begonia, the stalks, leaves and other parts of which are superficially studded with loosely attached cellular bodies, and that any one of these bodies, if placed under favorable conditions, will produce a perfect plant similar to its parent. The power of a part reproducing the whole is seen daily in the processes adopted and practiced by fruit growers. A mere stick of a grape cutting, providing it has a bud, will grow into a complete vine, and the same is true of willow and many other plants. In root grafting, a piece of root of apple or other tree, four or five inches long, is split for a distance of an inch and a

half from the end, and a twig from a branch of some other tree, after being whittled into the shape of a wedge, is inserted into the split, care being taken to have the liber of the bark of the twig exactly contiguous edge to edge with the liber of the bark of the root. In budding, the bark of a young tree or branch is slit vertically for an inch, and the bark each side of the slit raised from the wood by an appropriate instrument. The bud to be inserted is taken from its twig with a portion of bark of oval shape surrounding it. This bark is inserted on each side under the raised bark of the young tree, leaving the bud projecting from the center of the slit. The bark is then pressed down and bound with a band of cloth or a string. In growing, the bud receives the sap from the stalk and converts it into leaves, limbs and fruit after *its* kind, while if left to itself the same sap would have formed these parts after the pattern of the original tree. The same change in the destination of the sap occurs in the grafting process.

If a fresh water worm Planaria be cut up into pieces, each piece will grow into a perfect worm. The process requires four to five days in summer, and twelve to fifteen in winter. If the rays of a star-fish be cut off, each ray will reproduce a perfect star, the other four rays growing from its large or body end. The earth worm will grow from pieces like the polyp. Many of the reptiles are able to renew such parts as legs and tail. If either the tail or legs of a Salamander be amputated they will grow out with bones, nerves and muscles complete. The legs of a frog will grow again if they are amputated carefully. Bonnet saw a worm grow twelve heads in succession, a new one coming after each amputation. The horns and part of the head of a shell snail have been reproduced after being cut off.

The Gecko is a little animal belonging to the lizzard family. Its tail, which it sometimes loses, is naturally possessed of circular folds and tubercles. When the tail grows out again these folds are left off, and sometimes the tubercles. This circumstance has led some observers to think they had found a new species. The Triton, and various other amphibian lizzards, are able to reproduce their tails. A crab is able to reproduce a claw or even an eye. It is said that even as highly developed an animal as one of the Dipneusta, the Protopterus annectens, is able to grow a new tail. Two cases of the kind are cited by *Bastian.* The embryo of a tail of a frog being cut off in the egg and put into water, grew on to its full size and then died. A spleen removed from certain animals has grown in again. The tail of a lizzard will grow again, renewing its external size in two or three months, with the nerves, muscles, and vessels, but does not recover its tail vertebræ for two years. A dormouse grew a new tail after one had been cut off. The antennæ of the crawfish grow out in from six weeks to six months, ac-

cording to its age. The claws and tail plates are also reproduced, but slower. "With crawfish under a year old all the severed limbs grow again in about 70 days." "Their eyes will also grow again, and in one case two eyes came in place of one lost." (Papillon.)

The renewals of tissue are under the same law and process as the first embryonic development of them. The epidermis, hair and nails are all the same tissue. The crystalline humor of the eye is also from the epidermis, and grows again after removal, in the cases of dogs and rabbits, in a few months. Cataract of the eye consists in the crystalline lens becoming filled with opaque matter, and it is relieved only by the removal of the lens, which has never in human subjects grown again—perhaps because only *old* people have cataract. Its place is artificially supplied by very strong glasses, so that the patients can easily read thereafter. The derma of the skin, the vessels, the tendons and nerves, all repair their bruises and breaks. If a piece be cut out of a nerve, as the sciatic, the repair begins by the nerve matter at one of the cut ends forming into a grayish bunch, and pushing out along the former track of the nerve till it unites with the opposite end. "This bunch is made up of laminated tissue and nerve tubes more slender than the original tubes, but by slow degrees it enlarges, grows whiter, its fibres become complete, and after a lapse of from four to six months we have a nerve cord of new formation. Such a cord is reproduced even when a part of the nerve *six* centimeters, (2.36 inches,) in length has been removed." Its functions come gradually as it grows. Also nerves of different function have been joined—cut and crossed over to others they are not naturally connected with.

Cartilage also has been renewed in two months in dogs and rabbits, in experiments of Legros. The same man also proved the renewal of smooth muscle (i. e., involuntary muscle, as intestine). Fibrous muscle is also rebuilt by fresh muscle matter. Bone is also renewed. The periosteum is partly composed of a cartilaginous substance, which is shown to be bone in process of formation. If this periosteum be carried away from the bone and twisted among the tissues and muscles, it will turn to bone in the anomalous shape it may happen to be left in. And in case of fracture of bone this substance is furnished by the periosteum—or it may be by the core of the bone itself—to form new bone to fill the fractured crack and cement itself to the two ends.

As examples of what may be called distortion of crystallization in an organic body, the following from Spencer's Biology may be quoted: "When the hip-joint has been dislocated, and long delay has made it impossible to restore the parts to their proper places, the head of the thigh-bone, imbedded in the surrounding muscles, becomes *fixed* in its new position by attachments of fibrous tissue, which afford support

enough to permit a halting walk. But the most remarkable modification of this order occurs in un-united fractures. False joints are often formed—joints which rudely simulate the hinge structure, or the ball-and-socket structure, according as the muscles tend to produce a motion of flexion and extension, or a motion of rotation. In one case, according to Rokitansky, the two ends of the broken bone become smooth and covered with periosteum and fibrous tissue, and are attached by ligaments that allow a certain backward and forward motion; and in the other case, the ends similarly clothed with the appropriate membranes, become the one convex and the other concave, are enclosed in a capsule, and are even in some cases supplied with synovial fluid." (Biology, 1-187.)

Animal Grafting. A graft on a tree is a parasite living on the vital fluid of its host, yet transforming it to a homogeneity with its own tissues. The same in animal grafting, a particular tissue transferred to another person or to another place in the same person, retains its own nature and may continue to nourish itself and add to its size at the expense of its host, yet preserving its individuality. "The cells of the choroid of the eye placed beneath the skin of an animal preserve their vitality in that new region, and there they even become the starting point for a more or less extensive formation of similar cells." Transfusion of blood is the transfer of red blood cells from the arteries of one animal to those of another. The blood of a mammal may be transferred to a frog and continue to live there and remain distinguishable from the others. It is easy to graft upon the comb of a cock either spurs taken from the same bird or teeth from a mammal. A periosteal membrane, separated from the bone and grafted under the skin, will produce a new bone on its under side—even a few cells of the rudimentary layer adhering to that membrane (*i. e.* the cartilaginous layer) will grow into bone when grafted. "Goujon has brought about the production of bone by grafting marrow." The growth of a small bone was produced in a few months by inserting a few medullary cells (marrow cells) under the skin of a dog. These bony parasites will, after a time, become re-absorbed because they have no regular nerve and vascular supplies to keep them growing and renovated—otherwise a new nose might be made of bone. The growth of teeth is from a little sac or follicle. There are two principles involved in the growth, the enamel and the dentine, each of which consists of cells of its own kind, and neither will produce the other. If a follicle be removed from a very young puppy, it may be grafted and grow on the back of an old dog, to a perfect tooth. If the germ of the dentine or ivory alone be grafted, that will grow and produce ivory, but the enamel germ alone will not grow. Paul Bert cut off a rat's tail and grafted it into another part of the body, where it grew success-

fully. Also by inserting the end of the tail under the skin near the head, it grew there forming a handle to the animal,—afterwards cutting it in the middle there were two tails, and the new piece continued thus to grow, and the nerves and vessels accommodated themselves to the new direction of sensibility and nourishment. Siamese grafting—or joining two animals together—was also effected by Bert. A slit is cut on the side of two animals and the skin partly turned to face out; the two animals are then sewed together with these strips, face to face. In a few days the union is complete. Bert kept two white rats thus joined for two months, but they quarreled so, he separated them. He also thus joined a white rat to a Norway rat, and a white rat to a Barbary rat. If one of such a brace be poisoned it effects the other likewise, showing the union of the circulation. The union of cats with rats, and rats with guinea-pigs was also partly successful, and interrupted rather by the uneasiness of the animals than the incongruity of the tissues.

Renewal of destroyed skin is very successfully accomplished by covering the part with strips or shreds of skin from other parts of the body or from another person. Such grafts are generally complete in 24 hours. Even the skin of a guinea-pig has been successfully grafted on a man. The epidermis in these graftings must be accompanied with the sub-layer called the malpighian or color layer of the skin, as in the epidermis alone the cells are *too ripe.* These facts prove that the essence of vitality "does not depend on an indivisible spirit animating the body (mens agitat molem), but on an activity distributed among the minute particles that make it up, consubstantial with these particles and as variable in its characteristics as they themselves are in their structure. (*Papillon.*) In other words, "the total life of the individual is but the sum, the resultant of the lives peculiar to each anatomical element, the harmonious union of the simultaneous working of myriads of monads—the monads of Leibnitz gifted with life in different degrees from the bony cell almost inert and mineral, to the nerve cell in which a strong and fine fire burns unceasingly." Every one of the living corpuscles is a complete entity in itself—a simple animal reproducing by fission. The fundamental character, the mark of life, is nutrition and reproduction of cells.

There can be no doubt of the unlimited susceptibility of modification of organs and the disposition of the fundamental cells compatible with life, especially when the modifying cause is applied to the embryo or to the young. The same anatomical element shows the same composition in all living species, in the lowest as well as the highest animal, which is due to the fact that the nutritive materials are the same in all. The first germs of life coming into contact with matter compatible with their

increase, grew into such forms as the essential nature of that matter made necessary. The nature of this nutrient matter and the whole environment of the life germs, have remained practically the same from the beginning of life, and the progress of forms consists of the gradual combination of these elements of nutrition into organic bodies under the stimulus of the physical forces. It is perfectly safe to affirm that if the natural forces had been different, and the nutrient matter available had been different, the forms of life would have been totally different from what they are. If now these elements be artificially changed, there is no end to the modification that might be produced, requiring the time, however, of perhaps many human generations of effort directed to a definite end. Such modifications might be effected by a different arrangement of the molecules or cells to constitute the organ differently, or by a fundamental change of the constitution of the cells themselves by a change of the nutritive food or composition of the cells.

In man and the higher mammals the power of renewal is much reduced, and is limited to particular tissues, such as (1) "Those formed entirely by nutritive repetition, like the blood and epithelia, (their germs being continually generated anew in the ordinary condition of the body). (2) Those of lowest organization, and of lowest *chemical character*, as the gelatinous tissues, the areolar and tendinous, and the bones. (3) Those which are inserted in other tissues not as essential to their structure, but as accessories, as connecting or incorporating them with the other structures of vegetative or animal life, such as nerve fibres or blood vessels. (*Carpenter's Human Physiology.*) The repairing processes are much more active in the lower than in the higher animals, and much more active in the young than in the old. Numerous authorities have been produced to show that there have been cases of "spontaneous amputation" of limbs in fœtal life, and a subsequent partial renewal of the same, "and it seems probable, from the history of normal development, that in the cases in which perfect hands and feet have been present without the corresponding limbs, these hands and feet have been secondary productions from the stumps of amputated limbs, since any *original* defect of development would have affected the hands and feet, rather than the arms and legs." (*Carpenter.*) There is one instance on record "of the twice repeated production of a supernumerary thumb, after it had been twice completely removed; and one case in which the whole of one ramus of the lower jaw having been lost by disease in a young girl, the jaw had been completely regenerated, and teeth were developed and occupied their normal situations in it."

Morbid growths are thought, by Carpenter and others, to be due to morbid constituents in the blood, which automatically form themselves

into new tissues—(presumably governed by the peculiarity of the crystallization and polarity of their elementary or "physiological units.") He agrees with Mr. Simon in designating several of the forms of cancer as a manifestation of the existence in the blood of a peculiar matter appropriate for the construction of such an organic structure. Mr. Simon styles the cancer "a new excretory organ which tends essentially to acts of eliminative secretion just as distinctly as the healthy liver or the healthy kidney." This is disputed, and it is said by some physiologists that the matter of a cancer is composed of epithelial tissue. If this is true, the cancer is to be regarded as a graft of a foreign "physiological unit." Papillon says that cysts (bladders) have been found in the ovary "containing in their inner wall a *true skin* furnished with papillæ, epidermis, hairy follicles, hairs and perspiratory glands. Teeth even have been found developing in the abdomen."

In general, the activity of a part is the cause of an extra flow of nourishment to that part. This is true of muscles and nerves. After they are properly nourished they cannot be made to increase indefinitely in size by the mere presentation to them of a superabundance of food. The superabundance will go to the formation of a substance having another constitution or mode of aggregation—usually fat. But there are conditions in which growth seems to be limited only by the supply of food. Dr. John Hunter transplanted the spur of a cock from its leg to its comb. In consequence it appears of the superior vascularity of the comb, over the place with which the spur is naturally connected, it receives there an increased amount of nourishment, so that it continues to grow indefinitely. In one case, a spur thus transplanted grew in a spiral form till it was six inches long; and in another case it curved downwards and forwards like a horn, so that its end needed to be often cut to allow the bird to bring its beak to the ground in feeding. The different organized entities, which together form the body of an animal, seem to put upon each other a limit of growth, whereby a certain relative proportion is preserved between the related or contiguous parts which have been evolved in connection with each other. The spur on the leg used in connection with the leg, and getting its nourishment from the same sources, has developed in a proportional manner, determined by these relations. But when the spur is transplanted to an organ with which it has heretofore not been associated and influenced, it is no longer under such limitation, and may then appropriate all the food in reach.

The excessive nourishment of a part which causes its undue enlargement, is called *hypertrophy.* When there is hypertrophy of the muscles from any cause, the associated bones are also stimulated in growth. And this is shown not only in the increased size of the bones themselves

but also in the greater development of the ridges and processes for muscular attachment to them. The bones of the skull also accommodate themselves to the brain within, growing when required, to make more room. Sometimes it appears the growth is not sufficiently rapid from the edges of the sutures to keep the gaps closed up; in which case there may be an independent growth of small bones inserted in the sutures. These are called "wormiana ossa," from Wormius who described them. They are not found in base of the skull, but chiefly in the lambdoidal, sagittal and squamous sutures. If the brain decreases in size the skull accommodatingly thickens on its internal surface by the process called "concentric hypertrophy."

The excessive development of the involuntary muscles which sometimes takes place is usually, if not always, referable to extra work put upon them. "Thus an extraordinary hypertrophy of the muscular coat of the urinary bladder is often seen as a consequence of the obstruction to the exit of the urine in consequence of a stone in the bladder or a stricture in the urethra, so again hypertrophy of the muscular coat of the gall bladder may take place in consequence of obstruction of its duct by a gall-stone. Hypertrophy of the muscular coat of any part of the alimentary canal may be induced by the existence of a stricture lower down, and even hypertrophy of the heart is generally, if not always, attributable to obstruction to the exit of the blood which it propels, resulting either from stagnation of the pulmonary circulation by the deficient aeration consequent upon disease of the lungs (in which case the hypertrophy is limited to the right side of the heart), or from the thickening or induration of the semilunar valves, or from narrowing of the orifices of the aorta and pulmonary artery." (Carpenter.) All this extra growth of the parts is due to extra work and strain put upon them to meet the demands of their accustomed functions.

Tumors are to be considered as due to a species of hypertrophy, since they constitute an excessive formation of matter properly belonging to the parts to which they are attached. A tumor of the uterus, for example, is made up of an excess of its normal ordinary tissues, but forming a new organ out of them. This new organ, not having been developed in any sort of working relation with the other parts, is not limited by them as they limit each other. But it may excite the growth or hypertrophy of the uterus in the same way that its growth is excited by its normal contents when pregnant, and the uterus may thus acquire the power, under this stimulus, of sufficient contraction to separate and expel the tumor, as in an act of parturition.

Atrophy, the opposite of hypertrophy, is caused by want of nourishment supplied to the part, regardless of the cause to which such deficiency is due. A certain degree of activity is essential to keep any

organ in the proper condition to appropriate nourishment. Without such activity, therefore, it degenerates, first in its quality or potentiality, and second, in its size by loosing its degenerated tissue without acquiring new material in its place. The degeneracy of one organ often causes the disuse of some other with which it is related. If a motor nerve be paralyzed, the muscle whose movement depends upon it will become atrophied ; and conversely, if a muscle be disabled, as in case of hip-joint disease, or amputation of a limb, not only the nervous connections with the brain will become atrophied, but so much of the cerebrum itself as relates to the part will shrivel up and become functionless. Atrophy of the eye involves the disuse of the optic nerve and certain brain centers and their consequent atrophy, and vice-versa. When the muscles of a limb are reduced through disease, the bones are involved also and become lighter, as shown by experiments by Dr. J. Reid. (Carpenter.)

Herbert Spencer raised the question, what sort of units form the immediate constituent elements of the different tissues that go to make up the body ? That is, what are the little crystalline bodies which, by their polar structure, are fitted to be placed together to form a larger one ?

First, he shows that these units cannot be atoms (or molecules) of the complicated chemical compounds that enter into the composition of organic bodies—atoms of albumen, fibrine, gelatine, &c., for in that case there would be nothing to account for the unlikeness of different organisms "since so many plants and animals are mainly built up of such atoms." For since the polarities of the atoms determine the forms they compose, like units in all might be expected to develop all alike, which they do not. He therefore rejects these chemical units, and he likewise rejects the "morphological unit"—the name he gives the "cell"—as the unit sought. The cells it is true, compose tissues generally, but still they are not universal. "Finding that in many cases a fibrous tissue arises out of a structureless blastema without cell formation ; and finding that there are creatures such as Rhizopods which are not cellular, but nevertheless exhibit vital activities and perpetuate in their progeny certain specific distinctions ; we are forbidden to ascribe to cells this peculiar power of arrangement. Nor, indeed, were cells universal, would such an hypothesis be acceptable, since the formation of a cell is, to some extent, a manifestation of this same peculiar power. If then this organic polarity can be possessed, neither by the chemical units nor the morphological units, we must conceive it as possessed by certain intermediate units which we may term *physiological*. There seems no alternative but to suppose that the chemical units combine into units immensely more complex than themselves, complex as they are ; and that in each organism the physiological units produced by this further compounding of highly compound atoms (molecules) have a

more or less distinctive character. We must conclude that in each case some slight difference of composition in these units leading to some slight difference in their mutual play of forces, produces a difference in the form which the aggregate of them assumes." (Spencer.)

"It is well to recollect that an organic particle $\frac{1}{10000}$ of an inch in diameter in which our best microscopes may be incompetent to reveal the slightest differentiation of parts may be made up of 1,000,000 particles $\frac{1}{1000000}$ of an inch in diameter, while the molecules of matter are probably much less than $\frac{1}{1000000}$ of an inch in diameter. Hence in such a body there is ample scope for any amount of complexity of molecular structure." (Huxley Invert Anat. 15.)

A large part of the movement of the early embryo takes the form of *invagination* and *evagination*, an apparent pushing in and out of the various membranes. The manner in which the entoderm takes the place as the lining of the ectoderm is direct invagination, most clearly recognized in the case of the Bell-gastrula, from which the human Hood-gastrula is, however, developed, and in which the process is still really invagination. If a short stick were to be pressed sidewise against the side of a soap bubble till it was buried, the membrane of the bubble coming up on the sides and ends and folding over till the folds touched on top, the process would resemble the formation of the medullary tube, the stick being supposed to represent the position of the tube when formed. The sinkings and swellings of the several parts of the membrane represent alternate invaginations and evaginations. So the formation of many of the other parts is in imitation of the same process. The optic vesicle evaginated from the brain bladder, the cavity of the eye ball and vitreous humor invaginated from the outside, the invagination of the ear sac, of the mouth opening, the nostrils and the anus, the evagination of the tail, the limbs, etc., are other examples. And so are the sinking of the whole embryo down into the amnion sac, and the sinking of the whole embryo back into the skin layers by which process the yelk sac is pinched in two and the body cavity formed. This pushing in and pushing out, however, are not the real processes, but only the apparent results of other processes. As we saw in studying the segmentation of the parent egg, the segmentation of one set of cells at first goes on faster than the segmentation of the other. As each cell duplicates itself it simply spreads and extends the membrane of which it is a member. As the two membranes are attached to each other and one growing faster than the other, the only possible result is that the faster one will soon enclose the other, or invaginate it. But the process of rapid growth alternates from one set of cells to another. The energy of growth temporarily exhausting the capacity of one membrane for expansion, is transferred to another, while the first one pauses. It is like

the growth of a tree, or the putting out of leaves in the spring. The first leaves to grow are those most favored by light or warmth or moisture, and some will be quite formed before others are fairly begun. Some law, too, limits the growth of each leaf, causing it to continue the subdividing of the cells at certain places on the edge of the leaf, thus expanding those portions and forming the projections and inequalities, serratures and dentations to be found around the edges of the leaves. Thus we may suppose that while the sap or protoplasm is sufficiently diluted with moisture so as to be easily portable through the veins and veinlets, and there is a proper amount of warmth and moisture, the leaf will be larger, the marginal cells continuing to subdivide for a longer time and more rapidly while they are at it. But if there is drouth, the cell walls become hardened into woody tissue and resist subdivision. As soon as extension in one direction receives a check from any cause the nutriment is diverted to another direction and so the symmetry of the pattern maintains itself.

Darwin has called attention to the correspondence or correlation which prevails between certain parts of an organism; one part appearing to influence the development of another. Very often the reason of these correlations is obvious, but sometimes it is obscure.

Darwin observes that hairless dogs have imperfect teeth, and long haired and coarse haired animals are apt to have long or many horns. Pigeons with feathered feet have skin between their outer toes; pigeons with short beaks have small feet, those with long beaks large feet. Hair, teeth, feathers, horns, claws, nails and beaks are all modifications and products of the epidermis, and are all through it derived from the same embryonic outer plate or skin sensory layer. It is possible that this common origin may have something to do with the parity of development in these common products. Some circumstance in the environment, as a severe climate, might stimulate development of the epidermis, which reflected back to the skin sensory layer of the embryo (in reproduction) would give that layer an extra stimulation, and this in the next generation might appear in several or all the products of that layer. The correlation of long beaks with large feet in pigeons, like that of long neck with long fore legs in the giraffe, might be due to a mechanical necessity of the animal, supplemented by natural selection. The longer the beak the greater the variation of the center of gravity, which would tend to throw greater labor upon the feet with increase in their development. Parity of parts is a constant subject of selection, since when one part is subject more or less to another, the failure of one is at least the partial failure of two. Another case that Darwin cites is that "cats with blue eyes are invariably deaf," a very curious circumstance. Blue eyes are abnormal in a cat, and indicate an unhealthy

condition of the sensory layer of the skin, which is shown in the abnormal or deficient deposit of pigment in the eye. Pigment is an important part of the machinery for receiving the light and turning it into sensation in the eye, and it is also thought by some to have a like influence upon the waves of sound conveyed to the ear. (Bain.) Whether this be true or not, since the senses are all founded upon the same sensory layer, it appears probable that the defect which shows itself in the sense of sight might also do the same in another sense. Albinos and white animals are said to be less sensitive in both sight and smell, owing to some deficiency in the skin which involves a lack of the requisite pigment. According to Cuvier, the Camel, during the rutting season, exudes a fetid humor from his head. This curious correspondence is paralleled by the correlation between the horns and sexual functions of deer. Horns are normally developed in the males only, in all the deer species except reindeer. The rutting season immediately follows their development, but if the male be emasculated no horns grow. "One instance is recorded of a doe with a single horn, resembling that of a three-year-old buck, and on dissection the ovary of the same side was found to be scirrous," that is, indurated and functionally destroyed.

It will be remembered that all animals pass through an hermaphrodite stage of sexual development in embryo life, both sorts of sexual organs being started, and one set afterwards suppressed. In the case of the female deer mentioned above, obviously the female organs on one side only were brought forward, while their partial suppression on the other allowed for a partial development of the male organs, including the correlative horn. The possession of horns by the male deer probably relate to their contentions with each other during the breeding season, and have arisen by selection with reference to this competition. This is supported by the fact that "after attaining their maximum of development the antlers of these animals decrease in old age at each successive renewal," that is, decrease with decreasing virility. The "fetid exudation" from the head of the camel is doubtless the equivalent of what in the other ruminants is hardened into horns, and by selection turned into formidable weapons of defense.

As a fair example of the correlation of interdependent parts may be mentioned the cranial ridges of some of the anthropoid male Apes. which are made necessary for the attachment of very large muscles which work ponderous jaws, in which are set incisor and canine teeth of extraordinary size. A similar sequence of correlations exists in the Lion; beginning with the great teeth each of the other parts follows as a necessary accompaniment, ending with the cranial bony ridges. Similar habits of life in the two animals have developed a similar formation of parts, and the correlation of the parts is obviously due to their action upon each other.

The following may be named as examples of induced polar action in bodies which were neutral or whose magnetism was in a state of balanced tension :

First.—The action of the induction coil and other magnetic induction.

Second.—The building of crystals in a sluggish solution by the introduction of an active crystal.

Third.—The fermentation of saccharine substances, &c., by the action of ferments and digestion by diastase, ptyaline, gall, pancreatic juice, gastric juice, bile, &c.

Fourth.—Segmentation following the consolidation of the sexual elements in reproduction.

Fifth.—Inoculation and fermentation by zymotic disease germs.

CHAPTER XXXIX.

SOUND.

Sound is the sensation produced in us by the vibrations or pulsations of the air or other ponderable bodies, liquid or solid, when such vibrations are allowed to agitate the auditory nerve through the ear. Until these vibrations reach the ear they are simply vibrations, not sound. [1] They become sound through the medium of the auditory nerve and the brain cells with which it connects, just as the rotary motion of a water wheel becomes transformed into the vertical vibratory motion of a saw. The movement of the wheel is not sawing, but as such movement is in rapid sequence transferred to the saw, it becomes sawing in that instrument. It has been settled by experiment that the rapidity of the vibrations that make in us the sensation of sound, ranges from sixteen per second to about 40,000 per second. These are the extremes; the limits at both ends vary with different persons. The more rapid the vibrations the higher the pitch of the sound. If the vibrations are regular and of even length, the sensation is that of musical sound; if uneven and broken it is merely noise. Vibrations at the rate of 33 per second give the sound of low C, sixty-six vibrations give the C of the next octave, 132 of the next, 264 of the fourth, 528 of the fifth, 1,056 of the sixth, &c., doubling for each octave; the C at the beginning of the 8th octave requiring 4,224 vibrations for its expression. The beginning of the 12th octave requires 67,584 vibrations. But this rate of vibration is beyond the perception of most human ears, and while it is vibratory motion it is not sound, for it is not heard. Sounds, or the vibrations which produce them, are propagated at different rates through different

[1] It is important to bear this in mind, although ordinarily the term, sound, is applied also to the pulsations as they occur outside of ourselves—and so it will be in this chapter.

mediums. In air sound travels about 1,090 feet per second, in water 4,768 feet, in iron (at 68° F.) 16,822 feet, &c.

The ratio of the vibrations which constitute our musical scale are as follows:

c		*d*		*e*		*f*		*g*		*a*		*b*		*c*
1	:	$\frac{9}{8}$	:	$\frac{5}{4}$	:	$\frac{4}{3}$	:	$\frac{3}{2}$	:	$\frac{5}{3}$	:	$\frac{15}{8}$	:	2 or
24	:	27	:	30	:	32	:	36	:	40	:	45	:	48

Table Showing Number of Vibrations per second for each letter:

Notes.	1 Contra Octave C, B,	2 Great Octave C B	3 Small Octave *c b*	4 Once Marked Octave *c' b'*	5 Twice Marked Octave *c'' b''*	6 Thrice Marked Octave *c''' b'''*	7 Four times Marked Octave *c'''' b''''*
C	33	66	132	264	528	1056	2112
D	37.125	74.25	148.5	297	594	1188	2376
E	41.25	82.5	165	330	660	1320	2640
F	44	88	176	352	704	1408	2816
G	49.5	99	198	396	792	1584	3168
A	55	110	220	440	880	1760	3520
B	61.875	123.75	247.5	495	990	1980	3960

It is evident that the length of the wave or vibration must vary with the pitch in the same medium, and vary with the medium for the same pitch. Sounds of every pitch travel at the same rate per second in the same medium. The length of the wave of C, at the beginning of the great octave, found by dividing 1090 feet by 132 is, in air, 8 feet 3 inches. In water it is 36 feet and one-tenth, in iron 127 and $\frac{4}{10}$ feet. For the C in the next octave above, these lengths are to be halved, and are for air $4\frac{1}{8}$ feet, for water $18\frac{1}{20}$ feet, for iron $63\frac{7}{10}$ feet, &c. In all cases the vibration consists of the movement endwise of radii or spokes of the elastic substance, which is the medium of conveyance. These spokes are of the length of the wave. Starting at the point where the blow first originates the sound, which we may call the center of a globe, imagine these elastic spokes or rays to diverge in every direction, each one having a length of $4\frac{1}{8}$ feet. Surrounding this globe of spokes imagine another one consisting of four times as many spokes of the same length, all pointing to the common center. Outside of this is to be conceived another with nine times as many spokes. In short, add an indefinite number of these spheres, numbering them from the center 1, 2, 3, 4, &c. The number of spokes contained in each one will be the

square of its position multiplied by the number of spokes in the first globe. Thus, if the first globe has 100, the second will have 400, the third 900, the fourth 1,600, the fifth 2,500, &c. Now, imagine a blow at the center of this system that is powerful enough to drive endwise all the spokes in the first sphere a distance of one inch. The force of the blow is transferred from the first to the second tier. Each spoke in the first tier having to move four spokes, in the second it is obvious the force delivered to each spoke of the second tier will be only $\frac{1}{4}$ as powerful as the original impact on the first spokes, and the distance they will be moved, therefore, will be only $\frac{1}{4}$ as great, or $\frac{1}{4}$ of an inch. As between the second and third globes, the force of the movement of four spokes in the former will be expended in moving nine in the latter, and their endwise movement will be therefore $\frac{4}{9}$ as far as that of the second tier, or $\frac{1}{9}$ of an inch. Nine spokes of the third tier transfer their energy of motion to sixteen in the fourth, so that the sixteen move $\frac{9}{16}$ of $\frac{1}{9}$, or $\frac{1}{16}$ of an inch, &c. The distance that these vibratory spokes thus move is called the amplitude of the vibration, and this amplitude, translated in our auditory sense gives the sensation of *loudness*. It is plain how this amplitude must become rapidly less as the distance from the sonorous body increases. In fact, it diminishes in proportion to the square of the distance, and consequently the loudness of the sound diminishes in the same ratio, and dies away with distance till the amplitudes are too diminished to produce sensation. Obviously the end of the spoke next the center will be driven further than the end away from the center, the elasticity of the material allowing the spoke to shorten. Thus, in the above example the spokes in the sphere No. 1 would shorten $\frac{3}{4}$ of an inch, in No. 2 they would shorten the difference between $\frac{1}{4}$ and $\frac{1}{9}$ of an inch, or $\frac{5}{36}$ of an inch. In No. 3 they would shorten $\frac{1}{9}-\frac{1}{16}=\frac{7}{144}$ of an inch. In No. 4, $\frac{1}{16}-\frac{1}{25}=\frac{9}{400}$, &c.

If the spokes of the sphere should be composed of any other substance than air—as water, wood or iron, or partly of one substance and partly of another, the same principles govern the propagation of the vibrations, each substance, however, giving them the length and amplitude due to its peculiar molecular constitution. It is evident that the amplitude of the sound will be the same at the end of the first spoke in all conductors, regardless of the material of the conductor. Therefore a sound will be heard through steel at a distance of 124 feet, as loud as through air a distance of 8.3 feet. The sound of a blow (of the pitch of C, say) struck on a railroad track, will be conveyed to a listener standing beside the track at a distance of say 1090 feet, by two mediums, the air and the steel rail. The sound by the air will be a whole second in coming, and will have vibrated 132 times, and the loudness of the sound will be reduced to $\frac{1}{17424}$ part of what it was at the

point of origin. [1] The sound by way of the rail will reach the listener in $\frac{1}{15}$ part of a second in 8.8 vibrations, and will be about $\frac{1}{77}$ as loud as when it started on the rail, or 225 times as loud as the same sound brought by the air. It is well known that sound may be diverted from a straight line, as often observed in the echo, where having struck a solid body it is reflected back.

It may be reflected at different angles according to the position of the reflecting body with reference to the source of the sound; just as a ball is reflected from a wall in different directions according to whether it is thrown square against the wall or at an angle. Hence, if the spokes of sound be hurled against a concave wall they will be reflected in a manner to make them converge, and so at the point of convergence or focus the loudness will be greatly increased. Sound is said to move with greater speed in proportion to the *elasticity* of the conductor, and to be retarded in a certain ratio to its *density*. In passing through more than one conductor, a sound will consequently travel at different rates, that is, will have longer spokes in the more elastic medium and shorter ones in the more dense, although if it pass from one medium to another that is both more elastic and more dense, the elasticity might offset the density and the rate remain the same. The *shape* of the medium through which the sound passes must of course influence the direction taken by it. If the sound passes into a denser medium and it is thicker on the left than on the right, that is, wedged shaped, the spokes of sound will be shortened more on the left than on the right, and the spherical surface formed by their front ends will wheel toward the left, thus taking a new direction. If the denser medium be the shape of a convex lens or a globe, the spokes in the middle will be shortened more than those at the edges, and consequently the outside ones will all be turned toward the middle, the spherical front becoming flattened, and under proper conditions even made concave and consequently converging.

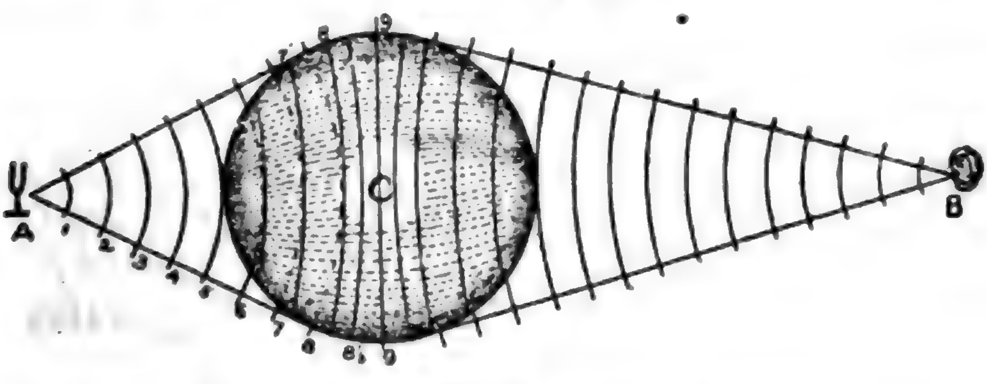


Fig. 158.—*Convergence of Sound by a lens.*

Fig. 158 shows how a sound pulse made at A is first flattened and finally made concave and converged into greater loudness at B by passing through a bladder of carbonic acid gas (C) which is heavier than air.[2] Every body upon being struck is caused to vibrate more or less accord-

[1] The speed in cast steel is 16,354 feet per second, at 68° F.
[2] See Gage's Physics.

ing to its elasticity. If the body is comparatively in-elastic, the vibration which it communicates to the air is momentary and it is called a noise. But if the body is elastic, it will give out a number of vibrations in regular time, and if the rapidity of them is so great that the impression made upon our auditory apparatus by one has not time to subside before it is assailed by the next, and the next, the effect is to produce the continuous sound which we call musical. Thus, noise is a mathematical point while music is a line. When a clapper strikes a bell a single blow it knocks it out of its circular form and compels it to take an elliptical form, with the long diameter in a direction at right angles to the direction of the blow. The stroke of the hammer creates one sound followed by the sound communicated to the air by the sudden change in the shape of the bell. The strained condition of the bell causes it to fly back toward its circular shape, but it flies further and takes an elliptical shape again with its long diameter at right angles to its first position, and so it oscillates from one position to the other a great number of times, each time communicating a vibration to the air. These vibrations follow each other so rapidly as to seem to our ears a continuous sound. Each strained position of the bell is a position of potential energy, and the force with which it descends from one such position is partly consumed in putting it in another. The part not so consumed is expended in the strokes upon the air which constitute sound and in work against the cohesion of the molecules of the bell which disappears as heat. These two gradually use up the energy of the stroke of the clapper so that the oscillations become less and less and finally cease. The molecular constitution and form of every elastic body determine the length of the vibration (or the pitch of the sound) it will communicate to the air when it is struck. Thus if an elastic string be stretched with a certain tension it will always give a certain sound when vibrated. If the force applied is strong the tone will be loud, but the pitch will remain the same as when the vibration is soft. The rapidity of the vibrations per second then is the same in both cases. The same law governs molecular vibrations that governs the swinging of the pendulum. A pendulum of a certain length always makes the same number of oscillations per second regardless (within limits) of the length of the arc through which it swings. When air in a tube or crack or any confined place is caused to vibrate whether loudly or softly the pitch is always the same for the same body of air thus confined.

This pitch is called its fundamental tone. Every simple body that vibrates at all—and very few do not—has its fundamental tone, which it emits on being struck. Every piano string, organ pipe, jewsharp, horn, kettle, pan, key-hole, bar of iron, strip of glass, bell, &c., has its fundamental note, and it will give only this when struck. A great

many articles that would hardly be classed as musical instruments, or even be thought to have any music in them, will often be found to join in when their note is sounded, showing that they are possessed of a susceptibility to some sort of vibratory impulse, however they are put together. Everyone has observed how piano strings, and other delicately adjusted instruments, can be vibrated by the voice, when uttered in the pitch of the string. This is simply the communication of the proper vibration from the voice to the air and from the air to the string. Certain tones of a large church organ will often cause the vibration of some part of the building or its furniture—as the windows, or chandeliers, or even the pews, and sometimes the people. Whenever any object trembles in response to a musical note it is evidence that it has a more or less perfectly developed fundamental tone. What the tone is depends on its material, its shape, state of molecular tension, &c. Bodies of irregular shape and uneven tension have more than one fundamental, different parts giving different sounds. When a shock to such a body sets all its tones in vibration at once, the result is a crash of discordant noises—as in a gong. But after two sounds are compared and found to agree as to length and amplitude of vibration, or pitch and loudness, there may still be a great difference between them. Let a flute, a violin, and a human voice all sound the same note at once, and though they harmonize perfectly it is easy to pick out each by its peculiarities. This individuality of sounds is called their *timbre.* It is scientifically proved that almost all sounds are composite and are made up of vibrations of different lengths or pitch in simultaneous action. When a violin string is vibrated as a whole, the result is the fundamental tone of the string; but beside the great vibration, the string divides itself into several parts, each of which sets up a sub-vibration of its own. It may divide into any number of equal parts, from two to seven. When it is divided into two the sub-divisions make two vibrations for every one of the whole string, thus giving the octave of the fundamental, as well as the fundamental itself. These additional or super-added tones are called the harmonics. As stated above, the C of the small octave is formed by 132 vibrations. Its possible harmonics are those only whose vibrations are multiples of 132. The first is the C of the second octave with 264 vibrations, the next is G of second octave 396 vibrations, then C of third octave 528 vibrations, E 660 vibrations, G 792, and lastly, the seventh harmonic having 924 vibrations with no representative note in our musical scale. Take the F string as another example, as follows: F′ with 176 vibrations, F′′ 352, C 528, F′′′ 704, A 880, C 1056, 7th harmonic 1232 with no corresponding letter. The human voice is rich in harmonics, and the peculiar timbre and individuality of each voice is due to the variety of the harmonics

and their varying proportional force. Almost all musical sounds are the resultants of such mixture of fundamental and harmonic tones, and very few musical bodies are free from the harmonics. But it is possible to construct such instruments, and Helmholtz has furnished them in what he calls the resonators. They consist each of a hollow metallic globe with a large open neck at one end and a small one at the other. They are constructed of various sizes and each one has only its fundamental tone without harmonics. Whenever the fundamental note of one of these resonators is sounded by another instrument the air contained in it is set to vibrating and thus reinforcing the sound, but it is silent unless its particular note is started. With these instruments the different, simple or pure sounds that go to make a composite note can each be picked out. It is in this way that the harmonics and accompanying sounds that go along with almost every fundamental tone have been sorted out and identified. We cannot fail to note in all phenomena of sound the paramount influence of the form and constitution of the mediums through which it is propagated. These mediums have nothing to do with the origination of the energy which finally is resolved into the sensation of sound. But they happen in its way and are acted upon by it, made to vibrate and to communicate their vibrations to the air. As energy acting on machinery of different forms and adjustments furnishes a variety of modes of molar motion, so when the molar motion is reduced to molecular vibration the form and adjustment of the body moved is all-important in determining the kind of motion developed in it, the period of the vibration, the length and amplitude of the waves, the number and pitch of the harmonics and the accompanying clangs and noises, or whether the vibratory movement results in any such phenomenon as sound at all. But no body whatever its form can escape being affected in some way whenever it is reached by the aerial vibrations. A molecular change of greater or less importance is inevitably accomplished, and if the body is a sonorous body these vibrations may pass on through it, exciting its fundamental tone on the way, and be again delivered to the air for further propagation. If the body impinged upon be an organized body the molecular vibration set up in it may be quenched in giving rise to sensation, that is, disappearing as one mode of molecular vibration it reappears as another. It cannot disappear from the domain of physics, nor be lost as physical energy. And it follows that if it does really disappear in giving rise to a sensation in an organism, that sensation is a form of physical energy. This important point is to be discussed further on.

It has been observed that sound is a vibration in ponderable matter. Accordingly we find that sound is not transmitted through a vacuum. A bell suspended by a string and rung in a receiver exhausted of air can-

not be heard. The molecular vibrations are there of course. The bell changes its shape, elongating its diameter alternately in directions at right angles to each other, but no air being there to take up the vibratory movement it is not conveyed to the ear and does not become sound. The effect of the vibration in this case would appear as heat in the increased temperature of the bell and this increased temperature might be carried across that vacuum. A small amount of the vibratory motion might be carried up the string and so out to the air as a faint sound, but only enough to prove that the absence of air inside is, as far as it is concerned, a perfect bar to such vibrations as produce sound.

It is important to understand clearly the nature of vibration in order to comprehend how it is that energy transfers itself from one body to another without the transfer of the bodies themselves. It is difficult to realize this without special attention. Let us suppose a clothesline to be stretched from one post to another. If the line be agitated at one end by a slight transverse blow, we shall see a wave travel along the line from that end to the other. It is plain enough that it is the *movement* that goes end-wise and not the line as a whole. Each small section of the line makes a little excursion first to one side then to the other, and it is these excursions taking place in one section after another in progressive succession that constitute the movement of the wave. As the force of the pull is communicated to the first section of the line in causing its transverse movement, so as the second section is started in motion by the first, it receives the energy of the first, transfers it to the third, &c., so the energy goes with the wave from one end to the other. It goes *with* it, neither before it nor behind it. By a properly contrived connection the energy and the vibration might be transferred at the end to another line, or to any other sort of elastic body, as a bell for example. Notwithstanding the line as a whole cannot be said to move endwise, yet a little further calculation will show that each particle of it does not only make a transverse excursion, but also a small endwise excursion forward and back. As each wave is formed, the section of the line concerned momently occupies the position of a diagonal or hypotenuse in relation to the general direction of the line, and, therefore, for the time, acquires additional length at the expense of the elasticity of the line, or what is equivalent in this case, at the expense of its slack. The same must be true of all sorts of vibration. If a pebble be dropped into still water the progressive series of concentric waves that results, in effect stretches the surface of the water by a change in the relative position of its molecules, because measured over the corrugations the superficial area is greater than while the water is level. In forming waves, therefore, the particles of the body in motion must move forward and back. This being the case a body not elastic could not take a vibratory

movement. The forward and back movement of particles involved in the wave motion of liquids is shown to take the form of minute vertical circles. The particle moves forward or away from the center of agitation on the upper segment of the circle and returns on the lower segment. In sound the movement of the particles of the vibrating body is directly away from and toward the center of agitation in right lines. In radiant heat and light, the vibrations are at right angles to the direction of advance, like the waving of the clothesline or the vibration of a fiddle string. It is in all directions from the central axis or, as it is styled, in every azimuth. Every one has some idea of concord and discord. When two simultaneous sounds are produced we generally notice that the effect of the blending is a smooth, even sound pleasing to the ear; or it may be harsh, grating, full of loud spots and low spots and generally disagreeable. The first we characterize as concordant, harmonious, &c., and the last as discordant and inharmonious. The pleasant or unpleasant effects on us depend upon the habit or cultivation of our auditory brain, or the inherited effects of the habit and cultivation of our ancestors. There are, in the relationship of sounds, certain actual conditions which make harmony and inharmony real and objective in nature, and it is the reflection of these real conditions, in our brain, that constitutes our cultivation and habit. The physical basis of this musical sense is found in the effect of the sonorous pulsations upon each other. A vibration of a sonorous body consists in its making, under the impulse of a blow, an excursion to the end of its amplitude and back again. The outward motion communicated to the air is called a condensed pulse, because the air is condensed within the limit of the length of the wave, or the length of the spoke referred to above, and this condensation answers to the shortening of the spoke by the blow on its end. The elasticity of the air causes it to recover from this condensation, and when it flies back it leaves behind it a stratum of rarified air for each wave, and this is called a rarified pulse. It answers to the lengthening of the spoke after its recovery from the blow of compression. Now, if two similar sonorous bodies near to each other are set to vibrating in such a way that the outward or condensed pulse is made by both at once, the result is an increased amplitude and a greater condensation to the condensed pulse, producing greater loudness. If the condensed pulse of one is made at the same instant as the rarefied pulse of the other, the two will neutralize each other, that is, the air remains still and no sound results. It is like two bodies running against each other from opposite directions; they both stop. This is called interference. There is often partial interference, in which sounds reduce without quenching each other. If two sounding bodies are not in unison, that is, have a different rate of vibration, they will, when sounded together,

produce an uneven sound. Suppose, for example, one vibrates at the rate of 100, and the other 101 per second. At first, as the vibrations run nearly in the same time, they will reinforce and create loudness. But when the first is making its 50th condensed pulse, the second will have made 50 and be on the return, or rarified half of its 50th, so that the pulses will be antagonistic and neutralize each other. From this point the antagonisms will diminish till the first has finished its 100, and second its 101 vibrations, when they will again be together, and the sound will be loud. This rising and falling of the sound is called a beat, and it takes place whenever two discordant notes are sounded together. The number of beats in a second, which will occur when any two notes are sounded, is always equal to the difference in the number of their vibrations per second. Thus when C and D of the great octave are sounded together, there will be eight and one-fourth beats. (See table.) In the combination of certain harmonic notes there do not appear to be any beats. If any letter and its octave be sounded together, each alternate vibration of the high one will be on the outgoing pulse, while the low one is on an ingoing one, but the regularity and evenness with which this occurs destroys the effects of beats. The phenomena of interference and the reinforcement of vibrations by each other, will be met with in discussing light and heat. In our scales from the note to its octave, is a natural skip, but the filling in between these two is artificial, and has been different at different times and with different peoples. Some account of this is given by Blaserna in his Theory of Sound.

CHAPTER XL.

HEAT AND LIGHT—GENERAL THEORY OF RADIATION.

Within the last fifty years it has been demonstrated that there is no such substance as caloric or heat, but that like sound, heat is our subjective sensation of a vibratory motion of the molecules of bodies. Heat in a body arises in the same way that sound does, by the transfer to the body of energy from some other body. Whenever work or molar motion is arrested as such it goes on as molecular motion, a part of which always appears to us as heat. If the molecular motion were always the same in the same bodies, of course the effect on our sensations would be the same. But, as we have seen, sounds vary greatly with the form and structure of the bodies vibrating, and with the rapidity of the vibrations in the same body.

So the manner in which we are affected by the forms of motion called light and heat depends on the fact that particular sorts of bodies are in

motion in a particular way. Referring to our table of tonic vibrations, in the last chapter, we find the G of the lowest octave is made by 49 and a half vibrations. If we call this the beginning of octave number 1, the G at the beginning of octave No. 2 has 99 vibrations, No. 3 is produced by 198, No. 4 by 396, &c. The G at the beginning of the 10th octave is formed by 25,344, and the 11th by 50,688. But this rate is too rapid to make any impression on our ears, probably because each succeeding vibration reaches the drum of the ear before the one preceding it has had time to produce an effect. The result to the ear is silence, but the vibrations may go on all the same, doubling in number for each octave. When the beginning of the 20th octave is reached, the G will be formed by 25,952,256 vibrations per second. The 30th octave takes, in round numbers, 26,575,000,000 vibrations, the 40th 27,212,800,000,000, and the 44th requires 435 and a half trillions at the beginning and 871,000,000,000,000 at the end, or the beginning of the 45th octave. These are large figures and difficult to be conceived. In order to count a million a day a man would have to count nearly 12 per second for the whole twenty-four hours. Although no one can count more than half so fast, even at that rate it would take over 2,384,000 years to count 871 trillions. Yet it is proved by satisfactory demonstration that this number of vibrations actually takes place in a second.

The G at the beginning of the 44th octave makes its impression upon us through the sense of sight, giving the sensation of that color which a metal takes on when heated to redness. If the heat be increased the color of the metal will change to bright red, then yellow, and with intimations of greenish and bluish tinges finally become white. In passing through these phases of color it has, in reality, passed through different states of vibration, the final white color representing simultaneous vibrations of all the notes in the 44th octave, from G to G. These notes represent all the colors that are visible to our eyes, and are designated by the seven names, red, orange, yellow, green, blue, indigo, and violet. In reality, the tones pass from one to another by imperceptible steps representing a gradually increasing rate of vibration, so that there is no definite boundary between the red and orange, for example, or between the green and the blue, &c. These intermediate steps constitute the tints and shades of color—too numerous to be named. Sunlight and the light of the electric arc contain all the vibrations of this 44th octave, and some notes both above and below it. By means of a prism these different tones can be separated from each other. A ray of sunlight allowed to pass through a slit or hole into a dark chamber, and then through a prism, and falling at last on a white screen, is analyzed by the prism, the different parts of the ray being caused to diverge from each other like the rays of a folding fan. And when the light reaches

the screen, the image, instead of being the shape of the hole it came through, is greatly elongated in one direction, forming a band, and is differently colored in the different parts. One end of this colored band is red, the other end violet. The red end is nearly in a straight line produced from the slit through the prism to the screen, this ray being bent but little in passing through the prism, while all the other colored rays are bent more than it, in the following order: orange, yellow, green, blue, indigo and violet; the last being deflected the most. This colored band is called a spectrum. The spectrum of sunlight, when it is obtained by passing the beam of light through a very narrow slit instead of a large opening, is found to be crossed by numerous dark lines. These were mapped on the spectrum, and some of them designated by letters by Fraunhofer, in whose honor they are called Fraunhofer's Lines.

Table showing Wave Lengths of various Colored Light, No. of Waves per inch, and No. of Undulations per second:

Place in Spectrum.	*Length of Wave in Inches.*	*No. of Waves per inch.*	*No. of Undulations per second, 186,000 miles per second.* (Trillions, Billions, Millions, Thousa's, Hundr'ds)
Line A Dark Red	.00002983	33,517	395,000,000,000,000
" B Red	.00002708	36,918	435,000 000,000,000
" C (Hydrogen)	.00002583	38,719	456,000,000,000,000
Orange	.00002441	40,949	483,000,000,000,000
Line D (Sodium)	.00002319	43.123	508,000,000,000,000
Orange	.00002295	43,567	513,000,000,000,000
Middle Yellow	.00002172	46,034	543,000,000,000,000
Line E	.00002072	48.286	569,000 000,000,000
Middle Green	.00002016	49,609	585,000,000,000,000
Line F (Hydrogen)	.00001906	52,479	618,000,000,000,000
Middle Blue	.00001870	53.472	630,000,000,000,000
" Indigo	.00001768	56.569	667,000,000,000,000
Line G (Hydrogen)	.00001689	59,205	698,000,000,000,000
Middle Violet	.00001665	60,044	708,000,000,000,000
Line H	.00001547	64,631	762,000,000,000,000
Ultra Violet	.00001354	73,855	871,000,000,000,000

It has been found that these dark lines are in consequence of portions of sunlight being intercepted or absorbed by incandescent gases floating in the atmosphere of the sun. If a bit of sodium or salt be vaporized in a Bunsen burner and then a ray from an electric lamp be sent through it and through a prism, a continuous spectrum will be formed having all the colors from red to violet. But across the orange there will be a dark line in the position marked D on Fraunhofer's charts. The D line of the solar spectrum is thus found to be caused by the absorption of some of the orange light from the body of the sun by incandescent sodium vapor suspended in its atmosphere. In like manner the line marked F on the spectrum is found to be due to the interposition of hydrogen. Other lines are caused by iron, some (H and others) by calcium, others by nickel, cobalt, manganese, potassium, &c. Twenty-two of the elements existing on earth have been identified in this manner, as also

existing in an incandescent vaporous state in the atmosphere of the sun. If any of these bodies heated to an incandescent vaporous state is allowed to form its own spectrum, such spectrum will consist merely of certain bright or colored cross-bands disconnected from each other instead of the continuous colored spectrum formed by sunlight or by an incandescent solid or liquid body. The number and position of the colored cross-bands of these discontinuous spectra vary with the bodies forming them, no two having lines in precisely the same position on the spectrum. But the position of all these lines in the bright spectra of the incandescent vaporous bodies forming them is identical

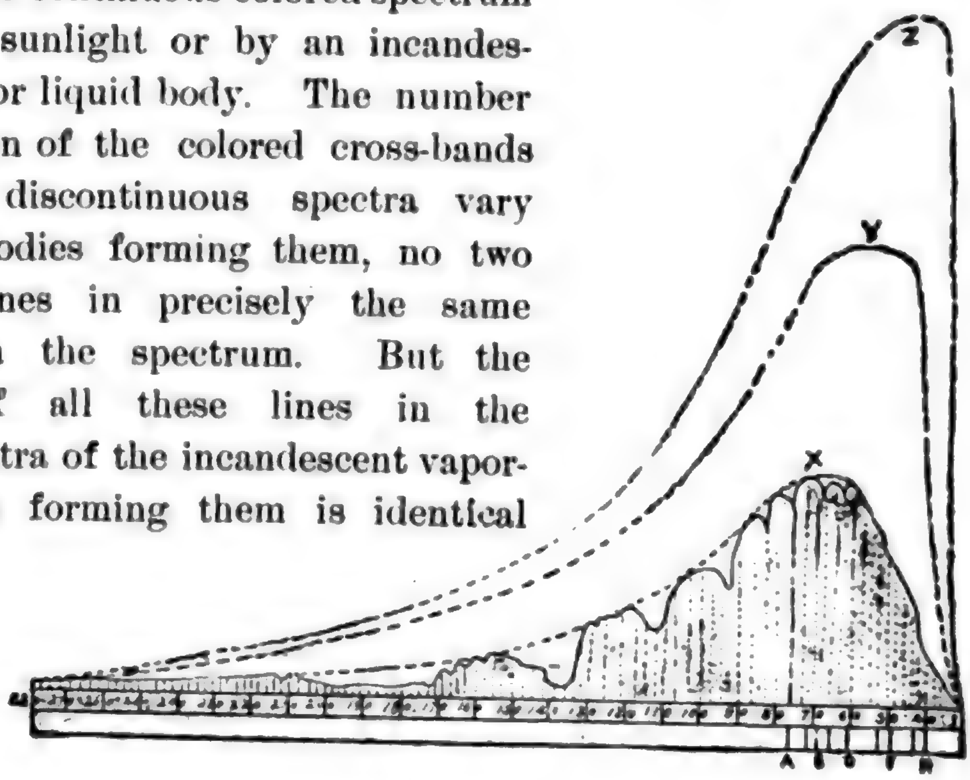


FIG. 159.—*Diagram showing Spectrum of Light and Heat rays of the Sun.* All lying to the left of 80 represents the invisible heat rays, that to the right of 80 indicates the visible part of the spectrum. The lines marked A and B are Fraunhofer's lines in the *red* part of the spectrum. D is the sodium line in the *orange* part of the spectrum. F is a hydrogen line in the *green*. H is in the *violet*. To the right of H and the left of A the spectrum fades into invisibility. The figures represent the *length* of the *waves* of the radiant energy, and stand for so many hundred thousandths of a millimeter. The dotted line X represents the surface of the earth and foot of mountains; Y is the top of the mountains, and Z the top of the atmosphere. The lines show the kinds of light and heat which predominate in the respective localities. Blue light is the prevailing light at the top of the atmosphere. (*After Prof. S. P. Langley.*)

with the position of the dark lines formed on the continuous spectrum of an incandescent solid or liquid when *its* light passes through such incandescent vaporous bodies. The whole number of these lines in the solar spectrum in the case of hydrogen is four, of calcium 75, of nickel 33, of manganese 57, of iron 600, &c. [1] Thus it appears 1st, that an incandescent solid or liquid body emits waves of all the lengths in the 44th octave, that is, from 435 to 871 trillions per second. (2d.) That an incandescent vapor or gas emits waves of certain lengths corresponding with only a portion of those emitted by the solid, some of one velocity and some of another. (3d.) That when the waves from the solid are absorbed by the vapor, they are reduced to stillness or darkness, their motion being transferred to other particles in the same body having a slower rate of vibration or fundamental tone whereby such particles are caused to vibrate in greater amplitude, thus increasing the degree of heat. A vapor when non-luminous has just the same effect as when it is incandescent, quenching light of the same color that it emits when hot

[1] Lockyer 245.

From the phenomena of incandesence in solids and liquids, we perceive that there exists in the incandescent body a great variety of fundamental tones while it is in the incandescent state, because its spectrum shows a great range in the molecular vibrations, no two rates of which are or can result from the same molecules or combination of molecules. [1] If a piece of platinum wire be heated by a voltaic current, and the effects studied in its spectrum, the first visible effect is red color, then, as the temperature increases, orange is added to the spectrum, then yellow, then green, blue, indigo, and lastly violet. But as each of these colors is added it is not done at the expense of the first ones; on the contrary, with each addition the ones already developed are intensified and become more vivid. That is, the *amplitude* of these lower tones is increased by the increase of the energy, but not their rapidity of vibration, because color is pitch, and the pitch and color change only by difference in wave length, and the wave length can change only as the form of the body in vibration is changed. The sounds made on a flute depend on the vibrations of the column of air contained in it, and that column is altered in length by the fingering—being shortest when all the finger holes are open, and longest when they are all closed. The platinum wire when heated is like seven flutes, each sounding a single note at one time—or, rather, like an indefinite number of flutes pitched to all the intermediate shades of tones in the octave. Therefore, although platinum is rated as an original element incapable of being analyzed or reduced any further, we are bound to conclude that when brought to an incandescent condition it undergoes a vast number of molecular rearrangements which are all maintained at once in its different parts, and each of which vibrates in its own fundamental tone. But more than this; if by means of a filter we cut off all the visible rays we shall find that the platinum is also radiating tones of vibration in one or more octaves below the visible rays. From what has been said of harmonics, we may reasonably infer that many of the tones in the upper octaves are the harmonics of the octaves below, induced by the increase of the energy of the temperature, in the same way as the octave is raised on the flute by simply harder blowing. But it appears to be an unavoidable conclusion that there are, in so-called homogeneous and elementary bodies, molecules of different forms. Heating a solid body to incandescence causes the breaking up of its molecules into so many forms that waves of all the lengths in the 44th octave appear to be radiated. But if the body be heated till it becomes a vapor, rays of a great many wave lengths are suppressed, and the spectrum, which before was a solid body, becomes reduced to a mere skeleton, a line here and there across the spectrum only remaining. This fact must be

[1] Draper's experiment.

interpreted to mean that the molecules of the body when in the state of an incandescent vapor, are more alike in form than when the body begins to solidify.

Recurring now to the fact stated above, that while sound does not pass through a vacuum both heat and light do, it may be asked, what is the medium through which they are conveyed? In the first instance, the origin of heat and light appears to be the vibratory movement of the molecules of bodies under the excitement of energy transferred to them from some other. The conveyance of this energy through the molecules of ponderable bodies—at least the lower forms of it which we call heat—is obvious enough. But it is not obvious how any form of energy passes across a vacuum, or how light passes through a solid body like glass. But the facts being undeniable that they do, there are only two ways of accounting for them. One is that impalpable, imponderable, invisible, infinitesimal bodies are emitted and hurled from the luminous bodies with inconceivable rapidity, from one end of the universe to the other, and pass with little hindrance through the pores of transparent solids, such as glass, &c. This is called the *emission* theory. The other is that all space, including the pores and intermolecular spaces of all bodies, is permeated with an elastic medium almost incompressible, capable of being set in vibration by the molecular agitation of a hot or luminous body, and that the vibrations of this medium when thus set going, propagate themselves in diverging rays until arrested by a ponderable body. This medium is called *ether*, and the theory which adopts it is the *undulatory* theory. This theory accounts satisfactorily for all the phenomena connected with the transmission of radiant light and heat, which the emission theory does not, and it is now universally accepted by physicists. Assuming the correctness of the theory, mathematicians have, by several various ingenious methods which verify each other, measured the wave-length of the various colored rays as they occur in the ethereal medium. The table of wave-lengths given above, refers, therefore, to the waves *in ether*. And the theory is that when a body is subjected to a violent molecular agitation, the motion is imparted to the surrounding ether and propagated through it in the form of undulatory vibrations at the rate of 186,000 miles per second. Light comes from the sun to us in about 8 minutes. In the case of sound the length of the wave differs according to the medium through which it passes. So the wave-lengths of light of the same color are different in different mediums, shorter in the denser mediums, and longer in the rarer.

The particles of ether enclosed in the intermolecular spaces of glass, water, mineral crystals, &c., are supposed to exist in a more condensed state than in the air or above it, so that the light takes a reduced ve-

locity in going through these transparent bodies, a reduction made by a reduction of wave-length but not of rapidity of vibration. Refraction is a consequence of the passage of the vibratory movement from a medium of one density to that of another. In going from the dense to the rare, unless it strikes perpendicularly to the surface, the beam of light is bent or refracted *from* the *normal*, or plane perpendicular to the refracting surface, while in going from the rare to the dense, the refraction is *toward* the *normal*.

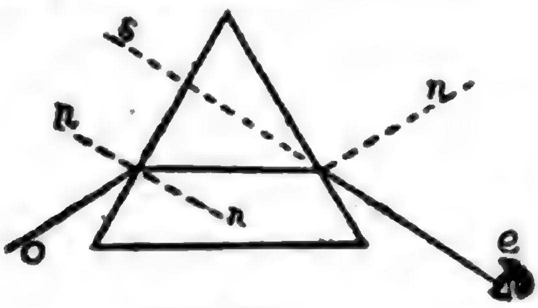


FIG. 160.

FIG. 160.—*Glass Prism showing refraction of rays in passing through.*
The ray from the object, *o*, upon entering the prism is bent and its track through is deflected toward the normal *n n*. On leaving, it is again deflected, this time *away* from the normal, so that the eye sees *o* in the direction of *s*.

A study of fig. 160 and a comparison with fig. 158 will show that the same principle governs refraction in both light and sound. The waves are shortened by going through the denser medium, and the greater the distance through, the more the beam will be shortened. The lower part of a beam, from *o* to *e*, fig. 160, will have a greater length in the glass than the upper part, and so the lower part will be made shorter, which will make the beam bend. If another prism were inverted and placed with its base up against that of the first, the object *o* would be seen at *e* by a ray passing through that prism also, but it would be bent in the opposite direction, and the two acting together thus, plainly indicate the principle of the lens.

The refraction of light in passing through a transparent gas is increased if the gas be condensed in bulk under pressure. In general, the greater the difference in density between two mediums through which the light passes, the greater the refraction in the passage from one to the other. The vibrations of radiant energy (heat and light) are at right angles, or normal, to the direction in which it moves. A fiddle string in vibrating may fly in any direction from its silent position; viz., to the right or left, or up or down, or at any angle intermediate of these. These various directions are called *azimuths*. Vibrations of ether must be conceived in like manner to take place alternately or under varying conditions in any and all azimuths.

CHAPTER XLI.

EFFECT OF BODIES ON LIGHT AND HEAT.

After being assured that light is not a substance, but merely the motion of a body entirely impalpable and invisible, it is somewhat difficult to realize that such motion could in any way affect or be affected by ponderable bodies. But in fact, *radiant energy*, which term comprises

light and heat as they come to us from the sun, constitutes the most powerful dynamic agency. Although it is only motion, it is motion of a real physical body, which is proved by the fact that it is influenced by the bodies it comes into contact with, and influences them in return. It is necessary to study these things in order to understand the manner and extent of the influence they have had in building up organisms, including ourselves, and keeping them in operation after they are built up. In this chapter there will be recalled some of the effects which are produced in light and heat by their encounter with ponderable bodies.

Law of Refraction, also called the *law of Snellius.* It was stated above that a beam of light is refracted when it passes from a rare to a denser medium, as from air to water.

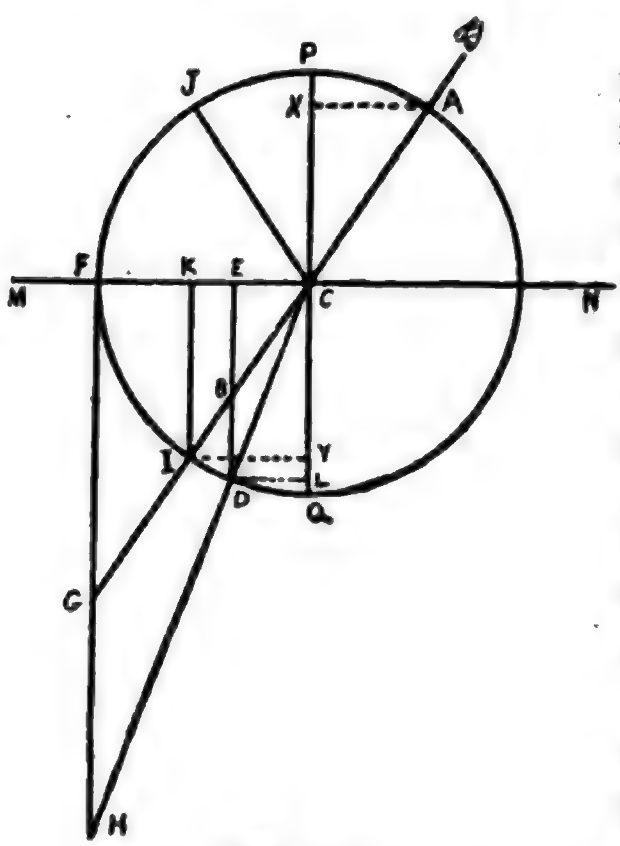


FIG. 161.

P Q, Fig. 161, is a normal or perpendicular to a reflecting and refracting surface, M N. A C P, angle of incidence equal to P C J, the angle of reflection. The law of Snellius is; that for the *same refracting substance*, the eye being supposed at A and the object seen really at D, but appearing to be at B, the line C B bears a constant ratio to C D, without regard to the inclination of the line A C to the refracting surface M N. Likewise the secants C G and C H are in the same ratio, and so are the sines of the respective angles A X and D L. But for different substances the angle A C H is different according to density when other things are equal. The constant ratio found by dividing A X by D L is, in the refraction between air and water $1\frac{1}{3}$ or 1.333; between air and glass it is from about 1.50 to 1.53 according to density; between water and glass about 1.14. (The index for *red* light is greater than that for violet, the former being 1.346, air to water, and the latter 1.333; this accounts for the colors of the rainbow.) The index for diamond is 2.5; for lead chromate 2.97.

Inflection or Diffraction. "If any very small object be placed in a pencil of divergent light admitted through a minute aperture into a dark room, its shadow will appear *materially larger* than it ought if light passes its edges in straight lines, and moreover, any opaque object, large or small, exhibits along the edges of its shadow a border of at least three distinctly tinted fringes, the brightest and broadest of which is next the shadow."[1]

[1] Prof. Barnard in Smithsonian Reports.

When two minute pencils of light are admitted through apertures very near to each other, the screen on which the blended pencils fall is streaked with lines absolutely dark. This is *interference.* In passing around corners some parts of the ray need to travel greater distances than other parts. When such difference amounts to half a wave length the crest of one wave falls in the hollow of another, and they neutralize and produce darkness. Various experiments illustrate this principle, as light admitted through gratings, &c.

Interference takes place in all wave movements when the crest of one wave falls upon the hollow of another. This is true of the waves of water, of sound, or of light. Whenever there is interference there is stillness, which in the case of the luminous vibrations means darkness. It has been stated that the vibrations of luminous waves are in all azimuths. Waves, therefore, occupy such relationship to each other that the front of some waves is presented to the *edges* of others. The front of the wave is in the direction in which its crest and hollow are alternately formed; the direction of its azimuth and of its activity. If a ray strike a mirror edgewise of the ray it cannot be reflected, for it has no activity or elasticity in the edgewise direction of the vibrations. Waves cannot interfere, therefore, when the front of one series is presented to the edge of another. Interference takes place only between vibrations which are in the same azimuth, or while they are in the same azimuth. Waves are naturally of different lengths representing the different pitch or color. If two waves of unequal length undulating in the same azimuth are traveling the same path, they must interfere at those points in which the crest of one overtakes the hollow of the other. So if the lengths of two waves are to each other as six to seven, at every 7th undulation of the shorter and every 6th undulation of the longer one they will interfere. As stated above, all light is retarded in passing from a rare to a dense medium. Now, if by any means a ray of such retarded light be made to mingle with a ray of the same color or pitch vibrating in the same azimuth, they will interfere, provided the retardation of the one has amounted to a half wave length at the point where they mingle. When such interference takes place there is darkness as to that particular color while other colors remain visible. This sort of interference happens when the two unequally retarded rays passing through a doubly refracting crystal are brought together again. (See on Polarization in this chap.)

The colors of *striated surfaces* are due to interference that destroys a part of the colored rays leaving the others to be reflected. This happens in the case of fine scratches on glass or burnished metal. The same conditions are realized when mother of pearl is cut and polished across the edges of the very fine layers of which the shell is composed. An

impression of this shell in black wax will have a like striated surface and will likewise reflect certain colors, the rest being destroyed by interference. Interference in such cases is caused by the reflection of some of the light from the sides of the fine furrows or troughs in such a way that it loses position to the extent of a half of its wave-length, and thus abolishes other rays of the same color not so altered. The colored rings of Newton are formed by a double convex lens pressed against the plane side of a plano convex lens. Light reflected from the latter lens will

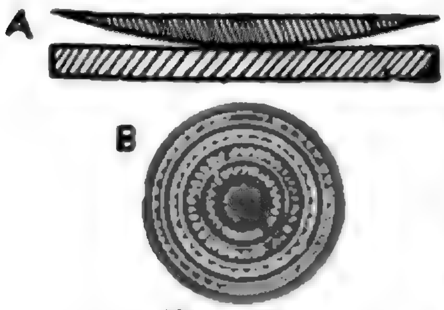


FIG. 162.—*Showing rings of Interference.*
A.—*Plano convex lens* on flat surface.
B.—*Plan* of *colored* rings formed by A.

FIG. 162.

take the form of colored rings alternating with dark ones. They occupy a certain mathematical relationship with one another, the squares of the diameters of the colored rings being to each other in the ratio of 1, 3, 5, 7, &c., and the squares of the diameters of the dark rings are as 2, 4, 6, 8, &c. Beyond the seventh ring the colored and dark rings are so crowded together as to become practically fused into one, white light resulting. The colors of the rings beginning at the center are: 1, black, blue, white, yellow, red; 2, violet, blue, green, yellow, red; 3, purple, blue, green, yellow, red; 4, green, red; 5, greenish blue, red; 6, greenish blue, pale red; 7, greenish blue, reddish white. This phenomenon is explained as the interferences between rays which are reflected from the first surface encountered by the incident beam; and those which pass through to the second lens and are reflected thence.

Double refraction. A beam of light passing through a crystal not homogeneous is divided, one ray being refracted according to the law of Snellius and called from that the ordinary ray, and the other is called the extraordinary ray. This is notably true in the case of the crystals of *Iceland Spar.* These crystals are large and are rhombohedral in shape; see fig. 163. The angles of the Rhomboidal face A, B, C, D are A and C 101° 55′ and D and B 78° 05′ respectively.

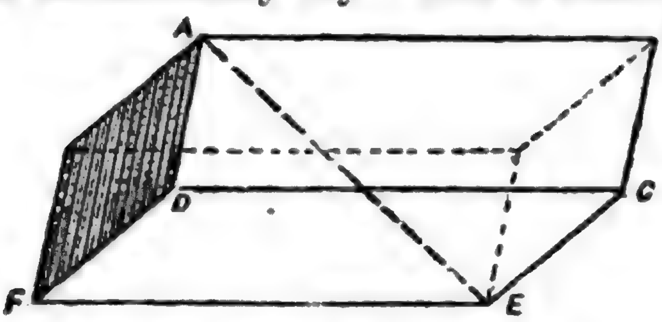


FIG. 163.—*Crystal of Iceland Sar.*

The angles of inclination D F E and C E F are 74° 55′ and 105° 05′. The shortest diagonal A E is the crystallographic axis.

If the angles A and E be truncated perpendicularly to the crystallographic axis, light passing through the crystal parallel with this axis will not be doubly refracted. Any such line is also called the optic axis. Any plane parallel with the optic axis is called a principal plane or principal section. Any plane at right angles to the optic axis may

be called a *conjugate* plane. In every conjugate plane the separation of the two rays by double refraction is at its maximum. Both rays in such case have their index of refraction constant (but different from each other). The index of the ordinary ray is 1.6543, and 1.4833 for the extraordinary. This difference of index explains why an object seen by the ordinary ray appears nearer than by the other. See fig. 161. The sine D L being shorter, the perpendicular D E is further to the right—nearer the normal, and the point B (or apparent position of the object D) is nearer to the point A, the position of the eye. Double refraction is always accompanied by *Polarization* more or less complete. In the Iceland spar crystal, truncated perpendicular to the optic axis, the extraordinary ray is bent further from the normal than the ordinary (as if repelled). (When the extraordinary index is greater than the ordinary, the crystal is called positive, when less it is negative.) In some other crystals the position of the rays is reversed, the extraordinary one being nearer the optic axis, which is parallel with the normal. In crystals of Iceland spar all the vibrations are quenched except in two azimuths, or are reduced to two azimuths, at right angles to each other, the vibrations of the ordinary ray being in one azimuth only, and those of the extraordinary ray exclusively in the other. It is important to get a clear idea of the polarization of light. It has been stated that a great many bodies are of such molecular structure that while they allow light to pass through them, they cause it to pass by boring through in a spiral manner. This was never known until polarization was found out. Let us illustrate by calling a beam of light a pine saw-log, which we are to imagine is to be sawed up into boards. A pine log may be divided into boards by vertical seams, each board being of even thickness but of different widths, the one in the middle being the widest and the others diminishing in width on each side. But with the beam of light it is different. All the boards to be sawed out of it are of the same width, and all maximum, and they are not parallel with each other. Only one of them is vertical, right out of the middle of the beam. Another is horizontal right through the middle of the beam in that direction and so at right angles to the first. And it is of equal width with the first. The other boards are to be sawed at all the various oblique angles between these first two, every board to be sawed directly in the middle of the log, and to be of the same maximum width. The waves of the material of this log are supposed to correspond with these different boards, the vibrations being always across the middle of the beam in the plane of some board. Consequently, they are said to be in all azimuths or directions from the center of the beam. The waves, as said before, must be conceived to be like those of a string stretched in the direction of the long axis of the beam.

If a full round beam of light is allowed to pass through a transparent body which causes it to twist or rotate as it goes through, there is no way of discovering that fact. If you roll over a saw-log it still presents the same appearance. If its grain is twisted from end to end it will, as a whole, be still the same shape. But if a plank is made to go through a crack which twists it, the amount of twist is seen upon the emergence of the plank. *Polarization* is a process by which a single plank of a beam of light is cut out of the middle of it and saved for use, the rest of the beam being thrown away. So the vibrations of *plane polarized light* are in only *one azimuth*, all the rest being cut off. We may imagine a number of beams polarized side by side, in which case we should have a number of planks piled together in a uniform manner. There is more than one way of obtaining polarized light. As said above, the light passing through crystals of Iceland spar is polarized in two azimuths, one at right angles to the other, so that two planks of a beam get through, all the rest being absorbed by the peculiar construction of the molecules of the crystal. *Tourmaline* is a crystal which polarizes light in only one azimuth—cuts a single board out of a beam and reduces the rest to heat. If light be presented to a slice of tourmaline, it allows only a flat board of it to get through, that is, the light is polarized. We can prove this by allowing the light to pass through two slices of tourmaline. The light which gets through the first will also pass through the second, provided it is held so that its plane of polarization corresponds with that of the first. But if the second be rotated to the right or left 90°, the crack which allowed the board of light from the first to pass through, is now turned crosswise, and the board cannot pass. But if the second crystal be turned another 90° it will be flatwise again and the light passes. Both of these crystals are polarizers, but when used as above the first is called a polarizer and the second an analyzer. Crystals of agate also have the property of polarizing light, and so have artificial crystals of iodo-disulphate of quinine. Light can also be polarized by *reflection* from different substances having smooth or polished surfaces; the angle required to produce the effect being different with different substances. When reflected from water the angle is 52° 45′ from the normal; with glass for a reflector the angle is from 54° 35′ to 58°. The angle of polarization depends on the refractive power of the body, "the index of refraction being tangent to the angle of polarization." And at the angle of polarization the reflected ray is perpendicular to the refracted ray. When a ray of common light is polarized by reflection, the plane of incidence and reflection is the plane of polarization also.

When polarized light is passed through thin laminæ, or plates of various crystals, as mica, selenite, quartz, &c., (when placed between a

polarizer and an analyzer) the light is colored with the tints of the spectrum. The analyzer and polarizer used are generally two *Nicol prisms* placed a little apart so that a film or lamina of crystalline mineral may be inserted between them. A nicol prism has a length three times its width, and is formed by splitting a rhombohedral crystal of Iceland spar along its optic axis, then polishing the cut faces and rejoining them with transparent Canada balsam, fig. 164, A D. In ac-

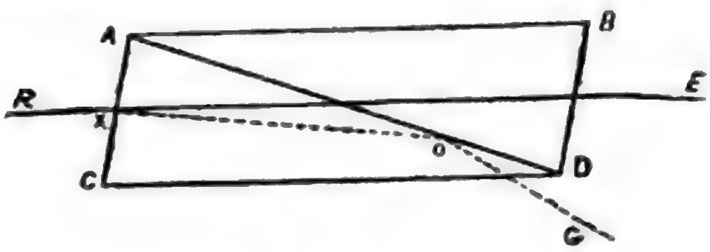


FIG. 164.

FIG. 164.—*Nicol Prism formed from Crystal of Iceland Spar.*
A D.—Optic axis.
R E.—Path of the extraordinary ray.
X O G.—Path of the ordinary ray.

tion the prism allows the extraordinary ray to pass through from R to E, the ordinary ray being refracted to O and totally reflected thence toward G and lost. The other ray is the one used as "polarized light." An analyzer can also be made with a transparent mirror, placed at the polarizing angle. The reflected ray being polarized in one plane, it follows that the refracted ray is made up of all the *other* planes or azimuths. If the mirror is not transparent this light is absorbed, if it is transparent this light is transmitted. By passing this through several plates of glass, "a bundle," it becomes polarized too. If two nicol prisms be used, the light passing through each is polarized—the extraordinary ray in each being transmitted and the other refracted to the side of the prism. If the prisms be parallel, that is, the plane of the extraordinary ray in one correspond with that in the other, the light that gets through the first will also go through the second, but if one is turned around 45° some light gets through—about ½ of it. But if it is turned around 90° so they are at right angles, the light that gets through the first will be cut off entirely by the second, and extinguished. If, however, a crystalline plate of tourmaline, for example, or mica, be introduced, having its principal plane at an angle intermediate to that of the two prisms, the light will pass, on the theory that it is partly turned in passing from the polarizer into the crystal plate, and finished up in the passage thence to the analyzer. As stated above, a single tourmaline plate cut parallel with its optic axis, transmits light in a single polarized plane. Two such plates together, with their axes parallel, will still transmit the light, since the azimuth of vibration into which the movement of the light is turned in the first is also permitted in the second. But if the plates be crossed, the light passing the first is totally extinguished by the second. But if a third tourmaline or a plate of mica be interposed with its axis oblique to both, the plane of the polarized ray from the first is twisted to a position at right angles from that with which it started.

A film of a crystal of gypsum, like Iceland spar, reduces the azimuths of vibration to two which are at right angles to each other. If a pair of nicol prisms be mounted in front of an electric lamp, and their axes crossed at right angles, no light passes. If a gypsum film be introduced between them in such position that one of its planes of vibration is parallel with that of the first nicol—the polarizer, its other plane of vibration will be parallel with the plane of the other nicol—the analyzer, and in that position the light is still cut off. But if the gypsum film be turned 45° in azimuth, its two planes of vibration will be oblique to both the polarizer and the analyzer, and the light will pass. That is, the light is polarized in the first nicol, the polarized beam is divided into two in passing through the doubly refracting gypsum film, and these two half beams get back together again in passing through the second nicol, the analyzer. But by the law of double refraction, in passing through the gypsum one of the half beams is retarded more than the other, so that when the two are brought together again in the analyzer, they are found to be vibrating in the same azimuth, but one a little behind the other. These are conditions of interference, and consequently the waves producing some of the colors in the white light are quenched, leaving the others to be transmitted. Chromatic effects of this sort must follow in all cases where plates of doubly refracting crystals of proper thickness are used. If monochromatic light, as red for example, instead of white light be used, and the crystalline plate be shaved to a wedge-shape, thinner on one edge than the other, the interferences can abolish only one color, the red, and a system of bands alternately red and black, is transmitted. If the crystalline plate be circular and of varying thickness, increasing from the center outwards, the alternate bands of color and darkness take the form of rings, these phenomena arise from the unequal retardation of the light waves in the crystal, thus shortening some of the wave lengths more than others. Whenever this difference in the shortening amounts to any multiple of *half-wave* lengths they interfere and are reduced to darkness. When it amounts to whole lengths or their multiples the colors are sustained. When white light is used it is of course the same as using lights of all the colors at once. And so the effect is to form a series of colored rings and dark interference rings for each of the colors contained in the white. But these various effects are so superposed on each other that the dark rings of one are covered more or less by colored light of others. Any solid double refracting substance whatever, whether mineral or organic, when it is made thin and is sufficiently transparent to allow the passage of polarized light, will produce chromatic effects of one kind or another when the separated rays are rejoined by the analyzer, because such structures produce double refraction on account of the quasi crys

talline nature of their construction. Among the organic substances "may be named horn, indurated jellies, tortoise shell, gums, resins, the crystalline lenses of fish or animals, &c." (Barnard.)

If a difference in the relative position of the molecules of a non-crystalline transparent body be brought about, as may be done by pressure, or strain or tension, it becomes, for the time being, doubly refractive and chromatic under polarized light. Thus, if a bar of glass be bent, it is on a strain and the molecules of one side are stretched apart, while the other side is compressed and the molecules crowded together. Light passed through the bar edgewise will be decomposed, because the wave lengths are unevenly shortened and therefore the emerging light will be colored. The same is true when glass is subjected to pressure, or to torsion, or to mechanical vibrations, or to uneven expansion by heat. Glass can be made chromatic permanently by being heated to the point of fusion and then cooled so rapidly as to leave the parts on a strain. Many articles of glassware are so imperfectly annealed after being formed that they are on such permanent strain, as tubes, and lamp chimneys, stems of wine glasses, stoppers of bottles, &c.

Rotary Polarization. If a plate of *Quartz* be cut from the crystal perpendicular to its axis, it possesses the power of twisting the plane of vibration to a degree depending on the thickness of the plate. When such a plate is placed between the polarizer and analyzer, and light passed through them, there results a single color. If the analyzer be turned in azimuth, say from left to right like a clock, the colors successively change, ascending the chromatic scale as from orange to yellow, yellow to green, &c. There are some of these quartz crystals, however, in which the analyzer must be turned the other way, from right to left, in order to cause the colors to ascend the scale. From this circumstance these crystals have been named *dextrogyre* and *lævogyre*, or right twisters and left twisters. If, instead of a nicol prism, a piece of Iceland spar be used for the analyzer in the experiment with the quartz plate both the refracted rays will be transmitted, and then it will be seen that the ordinary ray is of a certain color and the extraordinary ray is of the complementary color. If this analyzer be now turned the colors in each ray will progressively change, but each will always remain the complement of the other. Observe that the crystals that produce this gyratory progress of the light waves are cut across the optic axis and not parallel with it, so that we are to conceive the general direction of the light as with the axis, but its movement as spiral. In amethyst the structure appears to partake of both right and left gyration so that at the surface, lines of neutral character are produced. The explanation of this rotary polarization probably is, that the double refraction that takes place in the crystals sends two spiral planes of light in the general direction of

the optic axis, one gyrating to the right and the other to the left, one answering to the ordinary and the other to the extraordinary ray of refraction. When these two rays are passed through a nicol prism used as an analyzer, one of them is refracted out of sight and the other transmitted. When the Iceland spar is used the rays are separated, but not so greatly but that both are transmitted. If the apparatus be arranged so that the images of the two rays be superposed, one on the other, the resultant effect is pure white, which it should be if the colors of the separated rays are complementary. Another thing remarkable in consequence of its bearing on organic problems, is the fact that many liquids can produce rotary polarization. "The effect was first observed in oil of turpentine, but has since been found in most essential oils, in solutions of sugar, dextrine, the vegetable alkaloids, camphoric and tartaric acid, and the tartrates." Some are lævogyre and some dextrogyre. Narcotine in alcohol and ether, sulphate of quinine in water with sulphuric acid, and uncrystallizable cane sugar or molasses are lævogyre. The solution of *crystallizable* cane sugar, and the solution of grape sugar when prepared from the juice and before solidification are dextrogyre. But if dry grape sugar be redissolved it is lævogyre. Crystallizable cane sugar is made uncrystallizable by heat, and when this is done its rotary polarization is altered from right to left. The rotary power of many solutions is reversed by the addition of an acid. If to cane sugar one-tenth of its volume of hydrochloric acid be added, at 150° temperature, the rotary polarization is reversed. (Refer to page 218 for rotary polarization in glucose, &c.)

"*Magnetization of Light.*" This is the title given to the curious effects of magnetism discovered by Faraday in 1845. "If any homogeneous transparent body be placed under the influence of a powerful electro-magnet, it will possess the property, while the magnetism is maintained, of turning the plane of a ray of polarized light, traversing it in the direction of a line joining the magnetic poles, in the same manner as such a ray is turned by quartz or by liquids possessing the power of rotary polarization." In this experiment a pair of nicol prisms are used, one for a polarizer and the other an analyzer, with an electric lamp behind the polarizer, and between the nicols is placed a piece of homogeneous glass. The two ends of this glass are connected respectively with the two poles of an electro-magnet. As long as the planes of the two nicols are parallel, the light, polarized in the first will pass on through the glass and the second nicol. But if the second nicol be turned over 90° it will intercept the light. If now a magnetic current be passed through the glass the polarized plane of light is twisted over in the glass so it can pass on through the second nicol. Thus the glass is temporarily rendered either dextrogyre or lævogyre according to the direction

of the magnetic current. Another experiment is performed by using instead of the homogeneous glass, a peculiar crystal made by taking pieces of crystalline quartz plate, one lævogyre and the other dextrogyre, each having one straight edge by which they are cemented together. Such a crystal placed between the nicols while they are parallel will produce two different colors, one on each side of the cemented line. But by turning one of the nicols in azimuth, a position can be reached in which both halves of the image transmitted will be of the same color. If now a magnetic current be passed through the quartz crystal, each half will give an independent color and the two will be complementary of each other, as red and green; and if the current be reversed by changing the polar connections, the two halves of the colored image will exchange places, the red half becoming green and the green half, red. The effect is to cause a rotary twist in the plane of vibration the same as if the analyzer were turned in azimuth. These effects of magnetism endure only while the current is in action.

From what has gone before, it is fair to conclude that it is the variety of the forms of matter with which the waves of light come into contact that causes the variety in the phenomena. As in the case of the lower rates of vibration producing sounds which are modified, reflected or absorbed according to the form of the body with which the waves come into collision, so these higher tones called light are subject to the same accidents. When we speak of form, not merely the external configuration is meant, but the molecular composition also, which has much to do with the effects whatever be the rate of vibration. This is especially true of the phenomena of light just considered. Double refraction is always accompanied by polarization. But double refraction cannot happen to light passing through a homogeneous medium, and by this term is meant a medium whose particles are similar in structure and relative position throughout the mass. There are other crystals whose molecules are arranged in a symmetrical manner about lines running in some particular direction only. This is the case with Iceland spar as stated above. The shortest diagonal of the natural crystal is this "optic axis," every line running in that direction, *i. e.*, parallel with the optic axis, passes through tracts symmetrical on all sides at *any one place*. This is also true of ice, the optic axis being perpendicular to the plane of freezing. Light sent in this direction through ice or any other crystal, passes as if through a homogeneous body and it goes staight without being refracted. It is retarded if the light has come into it from a rarer medium, but this retardation manifestly can only bend the ray when it enters the crystal at an angle to the optic axis. In the case of double refraction the one ray is split into two, one of which is slower than the other; one half meets with a greater resistance than the other.

But when the ray passes into the crystal parallel with the optic axis, there is no refraction, and then the retardation of one half the ray being greater than the other half, one follows the other in the same track. This is one of the proofs that the vibrations of common light are transverse and in all azimuths, and that the vibrations of these two retarded rays are in different azimuths, and that the retardation arises from a greater hampering of the vibration in one azimuth than another; otherwise there is no apparent reason why one half of the ray could have a greater or less velocity than the other. But unless such difference of velocity existed there could be no difference in the refraction of the two rays, and no separation of them as there is when the light enters at an angle to the optic axis. The peculiarities in the crystallization of the crystals causing these results have in some cases been detected and pointed out. Sir John Herschel pointed out the peculiar crystallographic structure in the quartz that causes the right and left handed rotary polarization.[1] Besides the crystals that possess one optic axis or direction of no refraction, there are a great many that have two such axes. These are called *biaxal* in distinction from the *uniaxal*. Saltpeter is one of the biaxal crystals, the two axes having an inclination toward each other of 6°. Of course the chromatic effects resulting from this peculiarity are different from those of the other crystals.

Fluorescence. It has been stated that there are tones of vibration of the ether still higher in pitch than this 44th octave, which has been under discussion. One of the proofs of this is, that when a ray of light is analyzed by a prism, and a spectrum formed, photographs have been taken by the invisible rays above the violet of the spectrum. These invisible rays being more refrangible than the colored rays, belong, of course, to one or more octaves above the 44th. These rays were first named the actinic rays, and it was originally supposed that they alone, or chiefly, were concerned in the production of chemical changes, because if a strip of paper, saturated with a solution of nitrate of silver, be exposed in the spectrum, the greatest change will take place in the part exposed to the ultra violet rays, and the change will decrease downwards in the spectrum and be least in the red end. It does not follow from this, however, that the visible rays have no chemical power. One set of rays affect one substance, and another set another substance. The yellow rays are the most effectual in decomposing carbonic acid in the interest of vegetation.

Prof. Stokes, of Cambridge, England, discovered that certain substances exposed to the action of the invisible rays, emit light and become visible. He called this property *Fluoresence.* A number of bodies possess this property, among them sulphate of quinine, fluor

[1] See Smithsonian Report 1862, p. 135.

spar, uranite, and thallene. Paper prepared with these—as by painting flowers, or other figures, on the paper with the solution sulphate of quinine, &c., the figures come out in vivid color when exposed to the invisible rays, while they can scarcely be seen in the common light. "From the experiments of Dr. Bence Jones it would seem that there is some substance in the human body that resembles the sulphate of quinine, which causes all the tissues of the body to be more or less fluorescent. The crystalline lens of the eye exhibits the effect in a very striking manner. When I plunge my eye into this violet beam I am conscious of a whitish blue shimmer, filling the space before me. This is caused by fluorescent light generated in the eye itself; looked at from without, the crystalline lens at the same time gleams vividly."[1]

The physical cause of fluorescence is the reduction of the pitch of the tones of vibration, that is, the reduction of their time or rate of vibration per second. The reduction of the *length* of the waves takes place when the light passes from a rare to a dense medium, which has the effect to reduce the velocity of the progress of the light, but does not of itself affect the rate of vibration of the waves, and by consequence the color of the light. But fluorescence is caused by the reduction of the time or rate of vibration, and is precisely the same sort of phenomenon as the absorption of light by black bodies and its reduction to the invisible tones of heat. Almost all bodies have some such effect upon light. Some absorbing, that is, reducing, some or all the rays of light from the tones of the 44th octave to lower octaves. An opaque body that reduces *all*, appears black, one that reduces all but the yellow, for example, appears yellow, since that color alone is reflected and reaches the eye. If the body be transparent all the colors *not* transmitted are reduced to heat vibrations. Thus, blue glass is blue because all the rest of the vibrations are reduced to heat, and blue alone is transmitted, or transmitted in part and reflected in part. This leads to the further consideration of these *Heat Tones*. If they have the same physical basis as the tones of light, they ought to be subject to the same phenomena of reflection, refraction, double refraction, plane and rotary polarization, magnetization, &c. As the effects of heat cannot be seen, they must be observed by means of an instrument that can feel. Such an instrument is the thermo-electric pile. This consists of a galvanometer connected with a thermo-electric battery, such as that shown in fig. 145. Whenever the ends of the metals are heated to the slightest degree, a current is generated and the needle deflected. Experiments with the nicol prisms with non-luminous heat rays, result in the same way as with luminous rays. When the prisms are crossed, the heat passing the first one is intercepted by the second, and the needle of the pile remains quiet. But if

[1] Tyndall, Six Lectures on Light, 85.

a plate of mica be interposed between the nicols, the heat instantly gets through and the needle of the pole is deflected. If, instead of the mica, a plate of quartz crystal is interposed, the heat rays get through this also, showing the rotary polarization. The double refraction of heat in passing through Iceland spar is also shown by placing the pile in the path of either of the refracted rays. (Compare these effects with those of light, mentioned above.)

As many bodies are transparent to the waves of both light and heat, so there are some quite transparent to one and not to the other. A solution of alum in a glass cell, or cell with glass sides, allows all the light to pass, but effectually stops the heat rays. On the other hand, those chemical elements that are *gases*, also the elementary liquids, like bromine, and the liquid *solutions* of sulphur, phosphorus and iodine, are very transparent to heat.[1] When either the heat rays or the light rays are wanted exclusively, they can be sifted out by the use of a filter made of the appropriate material.

The resistance which different bodies offer to the passage of radiant heat through them is not the same for all sources of heat. Melloni experimented with heat from (1) a lamp, (2) platinum heated to incandescence, (3) copper heated to a temperature of 400° C and (4) copper at 100° C. The percentage of the heat from a ray of each of these sources which passed through different bodies as compared with air is shown in the following table. Each substance was made to be $\frac{1}{10}$ of an inch thick.

	1	2	3	4		1	2	3	4
Rock salt..........	92	92	92	92	Tourmaline (green)..	18	16	3	0
Sulphur	74	77	60	54	Common gum......	18	3	0	0
Fluor spar	72	69	42	33	Selenite............	14	5	0	0
Iceland spar........	39	28	6	0	Amber	11	5	0	0
Glass..............	39	24	6	0	Alum	9	2	0	0
Rock crystal........	38	28	6	3	Sugar-candy........	8	1	0	0
Felspar............	23	19	6	0	Ice	6	0.5	0	0

Rock salt allows nearly all the heat to pass through it, while alum, sugar-candy and ice allow but little to pass. Observe too that very different amounts of the different sorts of heat get through the same body. Thus 39 per ct. of the heat of the lamp gets through Iceland spar, while only 28 per ct. of the incandescent platinum heat, 6 per ct. of the 400° copper heat, and none at all of the 100° copper heat make the passage. The difference in the heat consists of difference in the wave lengths and the consequent periods of vibration, the hotter the radiating body the shorter the waves and the higher the pitch. So the above examples ap-

[1] Prof. Tyndall's Six Lectures. His light filter consisted of a cell of transparent bi-sulphide of carbon, in which some pieces of iodine were dissolved; the more iodine the greater the imperviousness to light, but the diathermancy or perviousness to *heat* is not impaired.

pear to indicate that the higher the pitch of the radiant energy, the more of it gets through. Experiments show that the same laws in regard to the transmission of heat govern in liquids and vapors. The hotter the source of the heat the more of it gets through. And, a liquid which can be vaporized behaves in the same way in both states; that is, it allows the same relative proportion of the heat to pass through in the liquid state that it does in the state of vapor. Water is a great absorber of heat both as a liquid and a vapor. The difference in the transparency of bodies to the waves of light and heat is due to the difference in their molecules, or rather in the spaces between the molecules and between the atoms which constitute the molecules. These spaces are occupied by the ether and every space has a fundamental pitch due to its shape, the same as a resonator has its fundamental for sound. If the ether waves from a hot body upon reaching another body do not happen to have periods corresponding to the fundamentals of the spaces in the body, they wiggle on through, as a sound out of pitch passes through a resonator without setting it in vibration. And these waves represent the *transmitted heat* if they be long waves belonging to the lower end of the 44th octave and to the octaves below it, or the transmitted *light* if they belong to the upper part of the 44th octave. The undulations that fail to get through the body are those which vibrate in *unison* with the fundamentals in the body and expend themselves in starting and maintaining by their continuous action, the internal vibrations in the body, which show themselves in the increased heat of the body or in the work of placing the molecules on a strain, as will be explained directly. This heat not transmitted through the body is said to be *absorbed*.

The mechanical nature of heat has been known for a hundred years. It has long been understood to be the energy of the vibrating molecules of a physical body, and the laws of its interconvertibility with other forms of energy are well understood. Wherever it ceases as heat, it is to be found as some other form of energy, either in action or potential. What is called "latent heat," it is now known, is energy expended in producing a rearrangement of the molecules in the body into which it has disappeared, and when this rearrangement is allowed to undo itself the energy consumed in its production again appears as heat. Thus, after ice has been raised in temperature to 32° F., it will require 143° more of heat to raise its molecular structure from that of ice to that of water, for after the 143° heat has been expended on it, it becomes water with a temperature of 32°. If now 180° more heat be expended on it, its temperature will be 212°—at which point the water boils. But still it is water, and now 967 degrees more heat may be expended on it before it becomes steam, and at that moment its temperature is still just 212°. So we know that the work of tearing apart the ice crystals in a

pound of ice is equal to the energy represented by raising a pound of water 143°, or 143 lbs. 1°, and the work of tearing apart the molecules of water represents the energy required to raise 967 pounds of water one degree. No two solid bodies at the same temperature contain the same amount of *heat.* Or, rather, if two bodies of the same temperature be cooled to a lower but still equal temperature, one will be found to have given out more heat than the other, and conversely if they both be raised to a higher but still equal temperature, one will be found to have absorbed more heat than the other, or, in other words, more heat is required in one case than the other, to give them the same temperature. It is obvious that the heat thus entering into a body and disappearing, becomes some other form of energy. When a body has any heat in it whatever, we are simply to understand that its molecules are being thrust asunder against their attraction of cohesion, and that as a resultant of the struggle between two opposing forces the molecules receive an oscillatory motion. We can suppose that the difference in the constitution of bodies is such, that a greater amount of energy will be expended in the production of a certain degree of oscillation in one than in another. And this is proved to be the case in all the solid elements. At every different degree of temperature their molecules occupy a different relationship to each other, and before a new degree of temperature can be manifested, the preliminary rearrangement of the molecules must be made, a process requiring the expenditure of a part of the applied heat in work, or cold motion. A part of the heat thus disappears in this work, and after the work is done the molecules upon which it has been expended occupy a position of potential energy toward each other, as is proved when the body is cooled by its giving out an amount of heat greater than the degree of fall in its temperature. We are to conceive here two forces at work, one of which is the attraction the particles have for each other—cohesion, and the other this foreign energy which counteracts cohesion and rolls the particles over into a constrained position against their polarity, without increasing the size of the body, or pushes them bodily asunder, thereby expanding the body as a mass. The quantity of heat going into a body is thus divided, only a part of it remaining as heat, and the quantity of heat which is required to raise the temperature of a body differs in different bodies. The subjoined table from Wurtz, gives the relative amount of heat required to raise the temperature of the different solid elements a given number of degrees, an equal weight of each element being used, and the heat required to raise the temperature of water being called 1.00. The quantities got in this way are called specific heats. In the first column of the table are given the specific heats, water being 1. In the second column are given the relative weights of the atoms of the bodies, com-

pared with hydrogen as one, and in the third column is given the product of the first two. It is called the atomic heat. The practical identity of the quantities in the last column proves that the specific heat is the same for *all atoms*, regardless of their name or weight. Or, in other words, it always takes the same amount of heat to raise an atom of any body one degree in temperature, and this, notwithstanding the fact that

Solid Bodies (only).		*Specific Heats.*	*Atomic Weights.*	*Atomic Heats.*
Aluminium	Al	0.2143	27.5	5.9
Antimony (Stibium)	Sb	0.0523	122.	6.4
Arsenic Crystallized	As	0.0830	75.	6.2
Bismuth	Bi	0.0305	210.	6.5
Boron Crystallized 233°	B	0.366	11.	4. (?)
" " 600°		0.5 (?)	11.	5.5
Bromine, solid	Br	0.0843	80.	6.7
Cadmium	Cd	0.0567	112.	6.5
Carbon Diamond 985°	C	0.459	12.	5.5
" Graphite 978°	C	0.457	12.	5.5
Cobalt	Co	0.1067	58.6	6.3
Copper	Cu	0.0952	63.3	6.1
Gold	Au	0.0324	196.2	6.4
Indium	In	0.0570	113.4	6.5
Iodine	I	0.0541	126.85	6.8
Iridium	Ir	0.0326	196.7	6.4
Iron	Fe	0.1138	55.9	6.4
Lead	Pb	0.0314	206.4	6.5
Lithium	Li	0.9408	7.	6.6
Magnesium	Mg	0.2499	24.	5.9
Manganese	Mn	0.1217	55.	6.7
Mercury (solid)—59°	Hg	0.0319	200.	6.4
Molybdenum	Mo	0.0722	96.	6.9
Nickel	Ni	0.107	58.6	6.3
Osmium	Os	0.0311	198.6	6.2
Palladium	Pd	0.0591	106.2	6.3
Phosphorus (ordinary) 19°	P	0.189	31.	5.9
Platinum	Pt	0.0324	196.7	6.4
Potassium	K	0.1655	39.137	6.5
Rhodium	Rh	0.0580	104.1	6.
Ruthenium	Ru	0.0611	103.5	6.3
Selenium	Se	0.0762	79.	5.9
Silicon at 232°	Si	0.202	28.	5.7
Silver	Ag	0.0570	108.	6.1
Sodium	Na	0.2934	23.043	6.7
Sulphur	S	0.1776	32.075	5.8
Tellurium	Te	0.0474	128.	6.1
Thallium	Tl	0.0336	203.6	6.8
Tin	Sn	0.0548	118.	6.5
Tungsten	W	0.0334	184.	6.1
Zinc	Zn	0.0955	64.9	6.2
Water	H_2O	1.0000		

the atoms of some bodies are many times heavier than those of others. To make this a little more clear, suppose the amount used of each element named in the table is 10,000 lbs., and that the figures in the column of atomic weights are pounds, and the figures in the column of specific heats represent so many heat units. Take Antimony, for example. Its atom weighs 122 lbs. Ten thousand pounds divided by 122 gives 82 as the number of atoms in that weight of the metal. This divided into 523, the units of specific heat, gives 6.4, nearly, as the atomic heat. Again, the atom of Lithium weighs but 7 pounds; so there are 1,429 of them in 10,000 lbs., which, divided into the 9,408 heat units, gives nearly 6.6 units to each atom. The wonderful fact shown in this table will be referred to again.

Spectrum Analysis. The manner in which the spectrum is produced by a prism was mentioned in the last chapter. There is another way of producing a spectrum, and that is by diffraction of light by means of gratings ruled on glass or on speculum metal. They may be ruled at the rate of 400 to the inch, and from that up to 20,000 per inch. The diffraction of the light analyzes it and produces the colors the same as the prism. They are not so bright as the prismatic colors, because the gratings produce several spectra which overlap each other. But they separate the colors in proportion to their several wave lengths, and they show the greatest heating qualities to be in the yellow and orange rays. The prism shows them in the invisible part of the spectrum below the red. It is thought that the prism gives too much dispersion to the violet and extra-violet rays, and too little to the red and infra-red rays. According to the prismatic dispersion, if the whole spectrum be divided into 320 parts, about 120 will belong to the visible portion, while the other 200 are divided between the infra-red and the extra-violet, giving the largest moiety to the latter. But by the diffraction spectrum a much longer proportion represents invisible heat and a much shorter proportion is above the visible violet. According to Prof. Roscoe, the total length of the observed spectrum is between three and four octaves, the visible part being but one.

As said in the last chapter, all incandescent liquid or solid bodies form continuous spectra, while incandescent vapors or gases form spectra made up of disconnected bands of color, scattered along in different parts of the space which would form the spectrum of a solid.

These discontinuous spectra are the signatures of the various alkalies, metals, gases, &c., when they are raised to an incandescent vapor. And no two of them make the same sign. The signature of some consists of only a few bands across the spectrum, others have many—iron has six hundred lines across the spectrum. If a number of substances, say a dozen or twenty, be mixed together and all vaporized by intense heat, each one will write its peculiar marks upon the same spectrum, and the spectroscopist can pick them all out and identify them with perfect ease and accuracy. There are, in the aggregate, some thousands of these lines, and yet only six of them are found to belong to more than one substance. These six belong to two each—unless better instruments with more dispersive power shall show them to be separated by a small space. Next must be noticed the extreme delicacy of the action of the spectroscope. Often a quantity of a substance so small that it cannot be perceived in any other way, will make its mark on the spectrum. The 18 millionth part of a grain of salt if vaporized will mark the D line across the spectrum. Indeed it is difficult to get a spectrum without having the D line (at first), because there is salt enough in the air

about the heating apparatus to volunteer to be vaporized and thus make its mark. A millionth part of a milligram of Lithium is big enough to write its name in legible characters. This metal was thought to be very scarce till the spectrum proved it to exist almost everywhere—in many kinds of rocks, in plants and in animal tissues, in milk and in human blood. Five elements, not known before to exist at all, were discovered by their unexpected writing across the spectrum. They are Cæsium, Rubidium, Thallium, Indium and Gallium. Newton, who first philosophized on the solar spectrum, was ignorant of the fact that it was crossed by many dark lines. This fact was discovered in the beginning of this century, by simply allowing the light to fall on the prism through a narrow slit placed parallel with the refracting edge of the prism, instead of through a round hole, as Newton had done. The narrower the slit the more distinct are the dark lines. In 1814, Fraunhofer, a German optician, counted and mapped these lines to the number of 576, and lettered some of them as we now have them. From this circumstance they are called the Fraunhofer lines. These lines were found to be fixed and constant in all sunlight, whether obtained direct from the sun, or by reflection from the moon, or Venus, or any other planet. It was not, however, till 1849 that it was proved what these lines were due to. Kirchoff, a German, formed an artificial continuous spectrum by means of a Drummond or lime light, and allowed this light to pass through a flame colored by common salt. The result on the spectrum was the dark line D in the very position in which the same line is a bright yellow one in the spectrum of salt alone. The same thing was done with potassium, lithium, calcium, strontium, barium and copper. Repeated experiments from that day to this have proved beyond all doubt that the solar spectrum is made up, first, of the continuous colored spectrum which every incandescent solid or liquid body gives, on top of which are piled, as it were, the discontinuous spectra of a great number of substances in a state of incandescent vapor or gas. It is shown that a vapor has the power of absorbing or quenching such of the rays that pass into it as have the same wave length as those rays which it ordinarily emits, while it is transparent to all the other rays. Consequently, when the light of an incandescent solid or liquid passes through the light of an incandescent gas, the spectrum of the gas is turned from a spectrum of colored lines to a spectrum of black lines, the position of the lines, however, being precisely the same in both cases. Since Fraunhofer's time many observers have watched and examined the solar spectrum. Over 2,000 lines have been mapped on the spectrum, and more than 800 have been identified as belonging to elements on earth. The following is a table of the elements and number of lines of each, determined by Prof. A. J. Angström, of Upsala:

	No. of Lines.		No. of Lines.
Hydrogen	4	Manganese	57
Sodium	9	Chromium	18
Barium	11	Cobalt	19
Calcium	75	Nickel	33
Magnesium	7	Zinc	2
Aluminum	2	Copper	7
Iron	450	Titanium	118

In addition to these, Lockyer gives cadmium as detected in the solar spectrum, and Prof. C. A. Young, of Dartmouth College, claims also iridium, sulphur, cerium and strontium. Thus we have 19 at least of our elements represented in the sun.

It was a theory of some of the English physicists that the sun had no atmosphere, but was itself a mass of cloud and that the dark spectrum lines were from gases mixed up in the mass. But at an eclipse in 1870 Prof. Young saw, in the few moments during which the sun was hidden, the dark lines of the spectrum all change to bright color lines. The same thing was observed in 1871 by others. This proves that the gases lie outside of the body of the sun, and when that body is covered up by the moon, these gases around the outer edge which are not covered by the moon are able to give their own proper discontinuous spectra of bright bands. The hight of this solar atmosphere is 400 to 1,000 miles. In like manner the spectra of many of the stars have been examined and carefully mapped. The two large stars, Aldebaran in the constellation of the Bull, and Betelguese in Orion, are near each other and so, favorable for comparison. Their spectra show about 70 lines. In that of Aldebaran there are two hydrogen lines, the sodiun line D, magnesium a few lines, calcium four lines, iron four lines, bismuth four lines, tellurium four lines, antimony three lines, mercury four lines. Here we have in this distant star 9 elements, at least, belonging to our earth; four of which are not found in our sun. Betelguese has the same elements except the hydrogen; only one other star has been found destitute of hydrogen. It must be observed that the small number of lines which each element registers in these cases is owing to the dimness of the light. It has been shown that as the amount of the material decreases or the intensity of light diminishes by increase of distance, the effect is to drop out lines from the spectrum, but the lines that are left are just as reliable as far as they go, and perfectly faithful to their positions. Nearly all the stars are found to be like our sun in general, though differing in detail. They all have the continuous colored spectrum crossed by dark lines, but the lines of no two are just alike. It was a question the telescope could not settle, whether the bodies called nebulæ were really hot, gaseous bodies, or only remote clusters of separate stars. Many such bodies had by the better and larger instruments been so resolved into stars, and it was believed by some that all would be in the course

of time. Over 70 have been examined by the spectroscope, ⅔ of which gave a continuous spectrum showing them to be stars, the other ⅓ gave the discontinuous spectra characteristic of gases. Nearly all of them yield the three lines shown on the diagram for the nebula in the constellation Draco. One of these corresponds with a line of nitrogen, one with the F line of hydrogen, but the middle one corresponds with no line of any known element. The reason no more lines are visible of the hydrogen and nitrogen, is plain enough when we are told that a sperm candle ¼ of a mile away is 20,000 times as brilliant as the nebula. Comets have also been examined. They have given the bright lines of the discontinuous or gas spectrum. But what gas, is uncertain, as the spectra are strange. It is something very light. Brorsen's comet, which is 60,700 miles in diameter and has a period of 5½ years, but which if solid could probably be put into a flour barrel is, nevertheless, self luminous. The spectrum of Winnecke's comet was found to correspond exactly with that of incandescent olefiant gas, from which it is surmised that its bright lines may be due to carbon.

One of the most wonderful properties of the spectroscope is its ability to detect *movements of bodies towards us or from us.* The explanation is very simple. If a luminous body is approaching us (or we it) the waves of light coming from it will reach us in greater rapidity than if it stands still. This will have the same effect as if the waves were shortened. Now, as we have seen, the shorter waves are refracted most on the spectrum, and so the band that represents those shortened waves will be found to be slightly shifted towards the violet end of the spectrum. On the other hand, if the body is receding from us, the waves will reach us less frequently and the effect will be the same as lengthening the waves. The corresponding lines on the spectrum then will be moved a little toward the red end.

Lockyer watching the action about a spot in the sun through his spectroscope has seen the hydrogen line F swaying in one part first toward the red end of the spectrum, then again, after awhile, returning to a straight position, and in another part it would deviate toward the violet end. Sometimes it would be a bright line, at others a dark line. His explanation is, that when the line shifted towards the red end of the spectrum, the cooled hydrogen from the upper solar atmosphere was rushing from us down upon the sun at a fearful rate, which was in some cases 38 miles per second. In another part of the spot at the same time, hot hydrogen was rushing up at the same rate, as indicated by the deviation of the line toward the violet end of the spectrum. Still more remarkable were Lockyer's observations on a cyclone on the edge of the sun. Here the storm was seen edge-wise, one part going from the observer and the opposite side coming towards him, as shown by the deviation of

the F line toward the red end in one case and the violet end in the other. The velocity of these storms is sometimes 100 miles per second. The hydrogen lines chiefly are affected by these storms, but the sodium, iron and magnesium lines are sometimes similarly affected. Many of the "fixed" stars examined by the spectroscope are in the same way found to be loose. In order to ascertain whether a line, the F line for example, of the spectrum of a star is out of place, it is necessary to introduce into the same spectroscope the spectrum of hydrogen, so as to have the two spectra side by side for comparison. This is done by an ingenious arrangement, and by these comparisons a great many stars have been found to be in motion either toward or away from our sun. In most cases the comparison was made with hydrogen, in one with sodium, and in several cases with magnesium.

The following are moving away from the sun: Sirius at the rate of 20 miles per second; Betelgeux, 22 miles per second; Rigel, 15; Castor, 25; Regulus, 15; five stars in the constellation of the Great Bear, 19; nine other stars, including Aldebaran, at various rates. The following are approaching the sun: Arcturus, 55 miles per second; Vega, 50; Alpha Cygni, 39; Pollux, 49; Alpha, in the constellation of the Great Bear, 53; and six others at rates not given. (Lockyer.)

There are some gases, some liquids and some solid bodies through which, at their ordinary temperature, it is possible to send a beam of light. If such beam, after passing through the body, is passed through a prism and made to form a spectrum, there will be the peculiar dark lines across the spectrum, due to the absorption of certain rays by the body. This fact is of great use to the chemist, who can, by that means, detect the presence of a substance in a compound or a solution, which it would be difficult to find in any other way. The air, with its contained gases, moisture, &c., has its peculiar lines of absorption which the astronomer is obliged to take account of. Thus we see there is no body of matter, big or little, that is exempt from the impact of the energy of ether in undulation, and there is none, big or little, that fails to deflect or re-direct, or to modify or re-form the energy and give it a different appearance. It is scarcely possible to conceive of a particle of matter so small as to be unable to make its mark across the spectrum. Nor can any imagination realize the distance across space, which is traversed by a ray that is shot from the sodium vapor of a fixed star to mark the "D line" in the little spectroscope of a mundane astronomer. Such ray may have received its send-off years before it reached the spectroscope. And of the myriads of other rays that started with it, a great number have fallen upon the earth and been degraded to heat, while the great majority have missed the earth and will travel on till intercepted by some other world.

CHAPTER XLII.

EFFECTS OF HEAT AND LIGHT ON INORGANIC BODIES.

It is a principle of physics that action and reaction are equal. Therefore, we must hold that whenever a form of energy is altered by transfer to and collision with a new body, the amount and value of the alteration is to be found in changes in the body itself. In other words, the body cannot change the form of the energy without suffering an equal change from its own former condition.

Having seen some of the changes effected in light by its encounter with ponderable bodies, we are now prepared for some illustrations of the way they are affected by it. We have already met with numerous examples of the effects of heat and light in the study of other topics. Thus the action of heat is essential in preparing the necessary conditions of temperature for all sorts of chemical reactions and all the phenomena of organic existence. And so is that of light. The service of light in connection with plant growth and the formation of starch, has been mentioned. The influence of these agents in bringing about the several allotropic states to which a number of the so-called original elements are liable, has also been mentioned. Thus heat at 290° destroys the molecule of ozone and enables the atoms to re-form themselves into oxygen. And either light or heat, under certain conditions, may convert oxygen into ozone.

Selenium, arsenic, sulphur, phosphorus and carbon are all changed by heat or light into their various allotropic states. Amorphous selenium is a non-conductor of electricity, but it is changed by heat into its crystalline form, in which it is a conductor. Its conductivity is much greater in the light than in darkness. In an experiment made by Willoughby Smith, the conductivity increased from 15 per cent. to 100 per cent. under the influence of the light of a common gas burner. It has been found that the resistance in selenium is in direct ratio to the square root of the illuminating power. But the most remarkable fact is that light shining on a piece of selenium is *instantly converted into an electrical current.* This current starts up and stops as rapidly as light can be turned on and off.

Chlorine also, as mentioned, may exist in two states, in one of which it is active, in the other passive. When it is prepared in the *dark* it is passive; and in this condition it may be mixed in a glass jar with an equal volume of hydrogen without a chemical union between the two taking place. But if the mixture be exposed to sunlight, the chlorine becomes "active," and hydrochloric acid is formed by the union of the two, with an explosion which may break the jar unless it be strong.

Horn Silver, or silver chloride, which is a native form of silver, is turned a dark violet by exposure to light for a few minutes. For this reason it has been much employed in photography. A number of substances that can be shaken apart by the action of light, are used in photography and other arts. Some of these will now be mentioned. *Lunar caustic* is silver nitrate. Anything smeared with a solution of it will turn black when exposed to the light. If a piece of paper be smeared with it and a flat object, like a leaf, be laid upon it and exposed to the light, all the parts not covered will be turned black, thus making a profile of the leaf. This is called a silhouette. Paper prepared with a solution of *Red prussiate of potassa*, and citrate of iron and ammonia is turned blue on exposure to the light. This paper is used for copying maps and other drawings. A tracing of the drawing is first made on transparent paper or tracing cloth, and this is laid on the sensitive paper, secured in a suitable frame and exposed to sunlight. All the parts not protected by the lines of the drawing are turned blue and become insoluble in water. The drawing is then washed, the water carrying off all the chemicals that were protected by the lines of the drawing, leaving them the original color of the paper—white.

Asphaltum (or the bitumen of Judea, &c.,) "is soluble in ethereal oils, such as oil of turpentine, oil of lavender, besides petroleum, ether and others." (Herman Vogel.) A film of this poured over a plate soon dries, becoming a light brown film of asphaltum. When this is exposed to light it looses its property of solubility in these ethereal oils. If a picture be taken on a plate prepared with this, and then the plate covered with oil of lavender, the oil will dissolve away all the asphaltum that was not exposed to the light. By taking advantage of this property, pictures were first taken in the camera in 1826. Copper plate engravings have been made with the asphaltum process by exposing the plate to an acid after the lines of the picture had been laid bare through the film of asphaltum. The acid would eat the lines on down into the copper while it has no effect on the parts protected by the asphaltum.

Chloride of silver, *Iodide of silver*, and *Bromide of silver* are all very sensitive to the action of light, and in consequence are of great use in photography. The action of the light upon these compounds is to shake them down to hypo-chlorides, hypo-bromides and hypo-iodides, compounds with molecules containing only half the quantity of chlorine, bromine and iodine; and the action is accompanied by a change of color. The chloride of silver is white, the hypo-chloride violet. Bromide of silver is light yellow, the hypo-bromide is a yellowish gray. Iodide of silver is yellow, and hypo-iodide green. These changes of color indicate that a change has taken place in the molecular constitution of the body, and it may be incidentally remarked that a change of color under

the same light indicates such molecular change in any body. A glass plate is prepared with one of the above compounds of silver or a mixture of them, and on being exposed (in a camera) to the light reflected from some body that is to be "taken," the brighter rays will most reduce the silver compound to the hypo-compound, and in some cases the $\frac{1}{100}$ part of a second is long enough to effect the change. This compound being thus suddenly torn to pieces by the action of the light, its pieces are free to form new combinations. A "bath" is made by mixing a solution of silver with a diluted solution of green vitrol from which a gray powder of metallic silver is precipitated. The picture that has been exposed to the light is immersed in this bath, and the free precipitate of silver finds its way to the parts of the plate on which the original coating of iodide of silver, &c., was most decomposed, and forms with it a new compound. The picture is next subjected to a pouring bath of hyposulphite of soda, which has an affinity for the original iodide of silver, &c., that composed the original coating of the plate, but which has no power over the new compound formed of the silver precipitate. All that remains of the original coating being thus removed, the parts changed by the light only remain. The picture thus formed is the negative, those parts which were black in the object taken being represented by naked places on the glass, while the light colored parts are represented by parts of the film of corresponding shape remaining on the plate. When this negative is laid on sensitized paper and exposed to sunlight, of course the positive picture formed on the paper is reversed, and the dark and white parts correspond with those of the original object. The paper used for the positive picture is prepared with white of egg upon which is formed a film of chloride of silver, by first moistening the paper with a solution of chloride of sodium, or common salt, and then laying it on a bath formed of a solution of silver, the silver joins the chlorine and the coating of silver chloride is formed. The process takes a minute, and when the paper is dry it is sensitive to light.

"*Chloride of iron* is not sensitive to light, but chloride of iron dissolved in ether is sensitive to light because the liberated chlorine unites at once chemically with the ether." (H. Vogel.) So iodide of silver by itself is but little sensitive, but mixed with nitrate of silver it is very sensitive because the liberated iodine has a body present with which it can make new combinations. So, in general, bodies which unite readily with iodine increase the sensitiveness of iodide of silver when mixed with it. "Among these bodies may be enumerated extract of copper, extract of tea, morphine, tannin."

Chromate of potash is another compound shaken up by light and used sometimes to make pictures. After paper prepared with it has been exposed to the light, it must be simply washed in clear water which dis-

solves the salts not affected by the light but leaves the parts that have been. Observe the mechanical difference effected by the sunlight in the molecular arrangement of this compound.

Gelatine is an organic product soluble in water, as is well known. But if it be dissolved with chromate of potash a compound is formed which when dried and exposed to sunlight is tanned and rendered insoluble in water. To take advantage of this property the chromate of potash and gelatine or glue must be dissolved together *in the dark*. Paper or other objects coated with a film of this compound and allowed to dry, still *in the dark*, may be used in taking pictures or silhouettes. The parts of the film which receive the rays of the light are rendered insoluble by the union in a new compound, of the gelatine and the chromate of potash, which union does not take place till the latter is torn apart by the action of the light. As long as they remain in the dark, although so near each other, they will not unite. The parts of the film not thus affected by the light are still soluble in water and are washed away in order to produce a picture. A mixture of acetic acid and nitric acid, which will eat steel, does not affect this tanned film, so that a picture made on a steel plate by this process can be eaten into the steel for engraving purposes.

The susceptibility of chromate of potash to light enables it to be used with aniline, under the influence of various acids, to produce a variety of colors. The aniline printing, invented by Willis, depends on the properties of chromate of potash. A curious use of the insoluble property of the tanned solution of chromate of potash and glue, was made by the Germans in 1870. Their army was largely fed on "pea-sausage," an article that is stuffed into pigs' intestines for safe keeping. The large demand for the food caused the supply of the natural cases to give out, and they resorted to artificial ones. These were made of blotting paper dipped for a second into sulphuric acid, then washed and dried, a process which makes it tough and impervious to water. This paper was cut into sheets and folded into cylinders, and the edges pasted together with a paste made from gelatine prepared with chromate of potash, as mentioned above. After being pasted, when exposed to the action of light the cement becomes insoluble, and the artificial tube, with its contents, can be boiled without coming to pieces.

One of the processes of photo-lithography, is to cover the stone (or zinc plate, in zincography) by sprinkling with a solution of asphalt in ether, allowing it to dry in the dark, and then placing a negative over it and allowing it to be exposed to light. The asphalt becomes insoluble on the exposed places, and is retained upon treating the stone with ether or benzine. If the stone is then damped, the moisture only penetrates where no asphalt covers the stone. On rolling it, after this, with

oily ink, this is rejected from the damp places and only adheres to the asphalt—that is, to the picture, thus a stone giving impressions is obtained. Another process uses chromium and gelatine.

Chloride of iron is another compound reduced by light to a hypochloride of iron, a bleaching process. If paper be prepared with a coating of chloride of iron, and exposed to light in a camera, the coating will be divided into two parts; the part affected by the light becoming hypo-chloride of iron. Red prussiate of potash will enter into combination with this hypo-chloride, while it will not with the chloride, so if a picture made by this process is immersed in a solution of the red prussiate of potash, all the light parts of the object taken will be represented in blue color, which, however, will not stand, but must be altered chemically to another color. Chloride of copper and chloride of uranium are also reduced by light to hypo-chlorides. The action of light is thus shown to be very powerful and rapid on certain bodies. On other bodies the action is more deliberate while not less effectual in the long run. If the crystals of *red sulphuret* of *arsenic* are exposed to the action of light for some months, they become disintegrated and fall into powder. *Glass* is also sensitive to light, the texture of most kinds being changed in a few days' exposure. An inscription of brass letters on a mirror in Berlin, was effaced after having remained some years. But the texture of the glass under the letters was found to be different from the rest of it, and yellow marks penetrated too far below the surface to be rubbed off. Glass containing manganese is strongly affected by the light. Manganese is sometimes made a constituent of glass for the purpose of discoloring it. But the action of the light undoing some of the chemical unions in the body of the glass, oxygen and manganese are left free to form the new combination of dark colored oxide of manganese, which then gives to the glass the dark color. In other minerals colors are sometimes changed by light. The *Siberian Topaz* is faded out from the fine golden yellow color it has in nature. A fine one, six inches high, in the Berlin mineralogical museum, was spoiled in that way. (Vogel.)

It is said the reason why bees exclude the light from their hives, is that honey, exposed to the light, rapidly crystallizes, while it does not in the dark. *Camphor* and *Iodine crystals* are formed, in a glass jar or bottle, by exposure to light in the same way.

But we are to observe that bodies are susceptible not merely to light in general, but that the different tone and pitch of the various kinds of light affect different bodies in different degrees. Indigo waves of light produce the greatest impression on the photograph plates as they are commonly prepared. Chloride of silver by itself, is most sensitive to violet, but is little affected by blue. Bromide of silver is affected by

green, and iodide of silver only by violet and indigo light. Various judicious mixtures of these compounds of silver of course are variously affected, and produce various artistic effects. But it is remarkable that bromide of silver, which by itself is not affected by tones below green, can be made sensitive to yellow, orange and red by mixing with it substances that absorb those colors. In this way it has become possible to take photographs with light of these lower tones.[1]

The *Fluorescent* property of *Sulphate of Quinine* has been mentioned. This property may be curiously taken advantage of to photograph invisible pictures. The picture is to be drawn upon paper with a concentrated solution of the sulphate of quinine. To the unassisted eye such picture is nearly invisible. But if photographed the picture "takes" distinctly black or dark. The reason is, that the rays which affect the chemicals on the photographic plate are the indigo, violet and ultra-violet, and that these rays when reflected from the sulphate of quinine are reduced in wave length and become perhaps green rays, which are not able to affect the chemicals on the plate. The effect then is just the same as if the drawing were black, which absorbs these rays (as well as all others). It is obvious that any kind of light that has the force to shake apart the chemical combination of the minerals on the plate, will take photographs. Such conditions are found in light from many different sources. The magnesium light, made by burning a Magnesium wire; the Drummond light, made by the flame from the oxy-hydrogen blow pipe blown against a piece of lime; the electric light, and light from an incandescent piece of iron, &c., will do to take photographs with, because they emit light of *all* wave lengths, including, of course, the violet and ultra-violet, so much concerned in this business. But those lights emitting an incomplete scale of tones, will not do unless the tones are those at the top of the scale. The white Bengal light of arsenic, the flames of the blue Bengal light and those of burning sulphur possess the requisite tones. But the tones of the common oil lamps, kerosene, and coal gas are too low, belonging to the red, yellow and orange part of the scale, chiefly. Yet, as before mentioned, these are the rays that effect the chief changes required in the growth of plants, and plants will keep awake and grow in such light. Light and heat being merely different periods of vibration of the same ethereal substance, there is no difference in principle between the actions of the two. When heat is absorbed, it is because waves of a certain period of vibration have found a place where their vibrations can be piled on top of each other in the production of heat or work in a body —that is, they become *sensible* or *latent* heat in a body. It is the same with light—when it is absorbed it may simply add to the heat of the

[1] A discovery of Vogel.

body absorbing it, or it may do work in separating the molecules of the body, the condition being, that the rate of vibration of the light waves fits the pitch of the interior spaces of the body.

Fig. 165.
Radiometer.

There is a little instrument, which was invented by Wm. Crookes, that shows how radiant energy can be converted into the motion of a mill. It is called a *Radiometer.* It consists of an air-tight glass globe, inside of which is a wheel consisting of four arms radiating from an upright shaft standing on a needle point, which allows it to revolve without friction. To each arm is attached a little plate of aluminum, which is black on one side and bright on the other. The air is almost completely exhausted from the globe. The light (with heat) of even a candle will cause the mill to turn, a hot sunbeam making it revolve with surprising rapidity. It goes in the direction indicated by the arrow in the cut, the bright side of the plates in advance. There is no way to make a perfect vacuum in the globe; and there is sure to be a quantity of *residual* air after the most complete exhaustion practicable. The motion is due to the action on the plates of this residual air which is set in motion by the external heat. When the radiometer is exhausted to a certain degree, the mill rotates most freely, but the exhaustion of air can be carried to so great an extent that the motion begins to be retarded, which proves that the action is due to the effect of light or heat on the *residual gas* remaining in the glass after exhaustion. When air in several radiometers is replaced by oxygen, hydrogen, carbonic acid, &c., and the globes are all exhausted to the same degree, the mills rotate at different rates, supposed by Carpenter to be due to the different rates of molecular vibration of the several gases. It is possible to compel the arms to remain still while the globe rotates. This has been done by fixing a magnet on the arms of the mill, then floating the radiometer in an upright position in water. Light then caused the mill to rotate. Then a strong magnet was brought near and the arms stopped, but the globe began to slowly rotate in the opposite direction. When the magnet was taken away, the mill began at once to go in the original direction, and the glass globe came to rest. The most powerful action of the radiometer is produced by the red rays—those strongest in heating qualities.

CHAPTER XLIII.

EFFECTS OF LIGHT AND HEAT ON ORGANISMS.

We will now turn our attention more particularly to the effects of light, heat and other dynamic agencies upon animal races in general, and our own in particular, in the production of special phases of development, in the creation of special functions and the erection by their means of special organs; most notably, organs of sense and organs of reflexion, whereby the impact of the forces upon the body is caused to reappear in new forms of motion. As shown in chapter 41, it is the waves that are pitched in unison with the periods of the fundamentals of the molecular spaces of the body that set up vibrations in the body and so cause it to do work. So, the action of those waves not in complete unison, tends to so differentiate the molecules with which they come into contact as to perfect the unison, and get the body gradually into a condition to be easily set in motion by the impact of the waves of force. This is the essence of the *habit* that has been insisted upon as the great differentiating agency in organic development. The organism is a plastic mass and may within certain limits be moulded to unison with various tones of the impinging force if only time be given and the force be uniform. We have seen that both of these conditions have been supplied, and as a result we see organs differentiated to sympathy with certain vibrations of ethereal energy. Something has been said of these in former chapters, but they will receive more particular attention in the chapters to come.

Some of the effects of light on animal organization are of common observation. Sunstroke is now known to be due to light. It may occur in the moderate weather of spring and may be caused by electric light. It is due to the action of the violet and ultra violet rays, and may be prevented by the protection of uranium glass which absorbs these rays. (Papillon.) Hemicrania, or sun-pain, is a pain of intermittent character involving only one side of the head and lasting only while the sun is above the horizon. But the effects of light go deeper than the skin, affecting the action of all the plastic tissues of the body. "Miners and others working in the dark are liable to undue preponderance of the lymphatic system, a susceptibility to catarrh in the mucous membranes, flaccidity of the soft parts, swellings and distortions of the bony system, &c." On the other hand, people of the tropics who go more or less naked are seldom deformed. Light gives to all the tissues their proper stimulus and the body is developed symmetrically. The fact is that a great part of organic movement is due to the impulses of light. When there is a cessation of these impulses the movement of organic develop-

ment will continue for a time through previously established *habit*, which is the momentum of former impulses, but will soon become erratic and in time cease. People living in dark places are unhealthy and their children are apt to be deformed. "Some poor people having taken up their abode in the cells under the fortifications of Lisle, the proportion of defective infants produced by them became so great that it was deemed necessary to issue an order commanding these cells to be shut up." (Robert Chambers.) In the absence of light, if other conditions are favorable, tadpoles will continue to grow indefinitely as tadpoles, but will never undergo their normal metamorphoses into frogs. If they are exposed to the action of green light alone they cannot undergo their metamorphoses. Their legs and lungs will not develop, their gills are retained, and after awhile they die. Green light is the same as darkness to them. It is said that the young of the medusæ (jelly fish) if confined in the dark will continue to form others by budding, thus remaining only polyps, and will go on in their development to perfect medusæ, only when properly exposed to light. The eggs of frogs will not develop in the dark. Those hatched under dark paper are abortions and rudimentary. Certain infusoria act under the influence of light in the same way that the chlorophyl zoospores do, moving into its influence from a shade.

Light directly affects both the temporary and permanent color of the different races of men, the habitual effects finally becoming hereditary and permanent. Many of the same race have been entirely differentiated from each other in color. Some of the Hindoos of the north are white, while those of the Deccan are black. The Jews, scattered through all countries have almost as many shades of color, from the fair white of the north of Europe to the black of Tunis. The Tuariks of Mt. Atlas are of a light brown, while those south of the great desert are black. The Esquimaux are whiter in winter than in summer. "It is believed that under certain circumstances fair races may become dark, and dark races light, the cuticle, however, being affected sooner than the hair or the iris of the eyes. In the southern, as in the northern, hemisphere, we we find a zone of lighter colored people running through the temperate regions. The Caffres of South Africa are not so black as the negroes of the tropics, and in South America the Patagonians and the Fuegians are lighter in tint and taller in stature than the races nearer the Equator. Some of the Araucanians of Chili are almost white The physical strength and great stature which distinguish the Northern Europeans are reproduced under similar conditions of climate among the Patagonians."[1]

It cannot be said that the differentiation of pigments in the animal

[1] Taylor's Origin of the Aryans, 100.

organization is due exclusively to light. We have seen that food may have something to do with it, and we are certain that temperature also has much to do with it, or at any rate radiant heat has. But there are abundant proofs that light stimulates the deposition of pigment matter and that there is a mutual action and reaction between the two. The probability is that the various sorts of pigments are influenced by various tones of radiant energy, both heat and light, and also by sound, by food and by the general vital energy of the organism. From what has been said of the colors of bodies we conclude that they depend exclusively on the molecular constitution and arrangement of the bodies and, therefore, whatever tends to alter this molecular constitution may change the color. As light among other agencies does this or contributes towards it, certain of the organic pigments must be regarded as subject to its influence. On the other hand no sooner does the new molecular change take place or the new pigment form than it begins to operate as a modifying agency upon the light It becomes a barrier to shut it off, to absorb it and reduce it to heat, or a filter to transmit rays of a certain tone while it refracts those of another. The ways in which the deposition of pigments is determined by the action of light, may be, and doubtless are, various. First, and principal, is the alteration of the molecular constitution, which without change of the constituent elements gives them a different refractive power on the light waves. This is a fact similar to that concerning the parallel effect of heat giving a new isomeric form and refractive power to the body without chemical alteration. Some examples of this effect of heat may be mentioned. Mercuric oxide, which is orange yellow, becomes orange red and brown when heated; chromic oxide is green, and when heated becomes yellow; cinnabar, which is scarlet, changes to puce; metaborate of copper is blue and changes when heated to green and greenish yellow. When these substances are cooled back to the ordinary temperature they resume their colors. Observing these changes to take place down the scale from shorter to longer wave lengths, they seem naturally to connect themselves with the expansion of the intermolecular spaces by the heat, the more expanded they are (up to the point of self-radiation) the lower the color. If, while under the influence of heat or of a similar action of light, the incorporation of foreign mineral substances takes place, a permanent change of color is effected. The coloring matter in animals is quite varied. Copper has been found in the red of the wing of the Turaco. Seven different coloring matters have been found in birds' eggs, several of which are chemically related to those of blood and bile. The same colors in different animals are not always produced by the same substances, as proved by the fact that the red wing of the Burnet-moth is changed to yellow by the action of muriatic acid, while the red of the

Red-admiral butterfly is not so affected. The colors of the epidermal products, as the chitinized skin of insects, also hairs and feathers, are often rich and deep and do not fade away after death. They may be considered the ripened products of the soft pigment layer below the epidermis. In this layer the colors are lighter and more vivid and usually fade after death. [1]

Green—the green of plants, must be the color that solar action alone would develop in an organism, the other colors, white, black, &c., being deteriorations from this. Copper-colored people retain the primitive coloring most nearly, while the yellow races are next. In the white and black the normal coloring is lost. In black the unassimilated (unburnt) carbon carried to the sweat glands in the blood and not oxidized there, leaves the pigment coat and its products (hair) of that color.

CHAPTER XLIV.

CHROMATIC FUNCTION.

Certain fish, as the fresh water Stickleback, Perch, Salmon, &c., change color to correspond with the color of their surroundings, a circumstance which makes them harder to be seen, and thus protects them. The power to make this change is called the chromatic function. The coloring matter, or pigments, in the skin of these animals, is found to lie in several strata at different depths. In the epidermis are pigment cells, which remain always the same size and so do not directly change the color of the animal. But in the cutis below are usually two or three layers of pigment cells, the top one immediately under the epidermis is a layer of light-colored yellow cells, beneath them red or brown, and in the deepest layer the black. "In some spots the pigment cells, of one kind or the other, may be wholly wanting, sometimes the black ones form a close mass in one spot, while in others the red or yellow predominate, but very few spots are devoid of pigment altogether." These pigment cells, like all protoplasm, are endowed with contractility under stimulus, and it is to this contractility that the change of color is due. These cells are called chromatophores. If they are all relaxed, brown or black will predominate. If the light colored ones remain relaxed while the dark ones are contracted, the pattern will be lighter, &c. It is now ascertained that the change of color is effected by the color of the medium in which the animal is, through the eye and optic nerve. If the animal is blind, or the optic nerve is injured, the change of color does not take place. The irritation causing the contraction of the chromatophores is found to proceed from the brain by way of the sympa-

[1] Sup. Pop. Sci. Mo., I to VI, p. 530.

thetic nerves to the cells in the skin. These are two nerves running longitudinally, close to the vertebral column, which connect with the brain and spinal nerves, and ramify to all parts of the skin. If these nerves are cut off at their roots, the chromatic function is destroyed, although it may go on even with the spinal cord itself cut off just in the rear of the brain. (Semper.)

Professor Dewar has shown that the different colors of the spectrum produce irritations in the retina, which are communicated to the optic nerve as an electric current, and is denominated the "optic current." "The intensity of this current, according to Dewar, is greatest under yellow light, weakest under purple light, and nil in total darkness." Applying this to the chromatic action of the chromatophores, the animal in darkness, or in dark surroundings, receiving no stimulus and no resulting optic current, and consequently no contraction of the chromatophores, remains dark like his surroundings. Light surroundings, on the contrary, will develop a current that will contract certain of the chromatophores, or all of them, giving a corresponding lightness to the color of the animal. If the light is reflected from colored objects, the contraction of the brown or black chromatophores will be partial, and the mixture of the color left in them, with the unchanged light-colored chromatophores, will produce other and varying shades.

Besides those named, the following possess the chromatic function: Turbots and Flounders, Frogs, the Chameleon-Shrimp (*Mysis chameleon*), Lizzards, Iguanas, Anolis, Cuttle fishes, Octopus, &c., and Chameleons. In many of these animals the function seems to be directly reflex, the action of light from the surrounding objects setting up nervous action in a direct path from the eyes to the chromatophores, without involving the general nervous centers (brain, &c.) in the stimulation. But it is possible to excite the stimulation of the chromatophores in some of them, especially the chameleon, through the general brain, by other stimulation than that of light. Thus, if the animal is at rest, his color simulates the objects with which he is in contact, but if he be stirred up by some other excitement, as a defense or contest, the stimulation overflows to the chromatophores, and he assumes all colors, regardless of their protective quality.

The chrysalis of a certain African butterfly (Papilio Nireus) has the property of becoming colored to correspond more or less truly with whatever body it may happen to be attached to. "A number of caterpillars were placed in a case with a glass cover, one side of the case being formed by a red brick wall, the other sides being of yellowish wood. They were fed on orange leaves, and a bunch of the bottle-bush tree was also placed in the case. When fully fed, some attached themselves to the orange twigs, others to the bottle-bush branch, and all these

changed to green pupæ, but each corresponded exactly in tint to the leaves around it, the one being dark, the other a pale, faded green. Another attached itself to the wood, and the pupa became of the same yellowish color; while one fixed itself just where the wood and brick joined, and became one side red, the other side yellow." "It is a kind of natural photography, the particular colored rays to which the fresh pupa is exposed in its soft, semi-transparent condition effecting such a chemical change in the organic juices as to produce the same tint in the hardened skin." The range of colors, however, which can thus be imitated, is limited to those which usually occur in nature, in the environment of the animal; a limit doubtless fixed by inherited habit. Thus they do not become scarlet in any case. (A. R. Wallace.)

We thus have examples of color marking by direct action of the color without the intervention of a sense organ. But in those more complete organisms in which a color sense becomes developed, that sense proves to be the most available path of access to the organism for the stimuli of the various colors; the color sense being taken from the general tissues and concentrated in a special organ. As long as the light rays act directly on the undifferentiated eyeless protoplasm, we can understand that many colors and shades might be developed in it, in an indefinite and undetermined quantity. But when the influence of the light is confined to one avenue, the nature and capacity of which can be learned, and is necessarily a definite quantity, we can understand that this influence is now measured and bounded by the degree of differentiation of the organ. We might therefore presume that those animals which are marked through the eyes, would not be highly colored unless the eye were a good one for distinguishing color. Accordingly, we find that birds are more highly colored than other vertebrates, and they have the finest color sense. Among the mammals the monkey tribes, next to man, have the best color sense, and many of them are adorned with brilliant red, yellow, green and blue sexual colors, whereby they are more conspicuous or attractive. Nocturnal animals are rarely colored.

Any special distribution of pigments in the organic system, may become so constant in its repetitions as to become hereditary, like other habits of organic action. Accordingly, we know that colors of the skin and appendages are largely hereditary—as in birds, the tiger, zebra, and many other mammals. It has been observed that certain pigment cells that appear in the cutis of the embryo chick about the fifteenth day, disappear again by the twenty-third. The embryo mammal is covered with colored hair, and the coloring of butterflies is developed in the pupæ in the dark. This proves the heredity of color habits. The extent to which the coloring of animals is affected by their surroundings, is apt to escape our notice. It is a fact observed by many nat-

uralists, that animals are often like their surroundings in color. Thus the "inhabitants of the deserts, the Jerboa, or leaping mice, Foxes of the desert, Gazelles, Lions, &c., are mostly of a yellow or yellowish-brown color, like the sand of the desert. The polar animals, which live surrounded by snow and ice, are white or gray. Many animals change their color in summer and winter, getting gray or blackish in summer, and white in winter. Many insects, like plant lice, &c., living on green leaves, are green, others, like butterflies of gay color, hover about bright colored flowers.

Hæckel also observes that many sea animals are bluish or completely colorless and transparent, like the water they live in. Certain fish—the Helmicthyidæ—are so transparent that a book can be read through their bodies. Then there are, among the mollusks, the finned snails (Heteropods) and sea butterflies (Pteropods); among worms, the Salpæ, Alciope, and Sagitta; among the crustacea, a great many crabs; among the Cœlenterates, the most of the jelly fishes, &c., all of which, living on or near the surface of the water, are transparent and without color, while their relatives of close kin, which live at the bottom of the ocean, are colored and opaque, like animals on land.

Everybody agrees with Darwin, that natural selection has much to do with the preservation of those animals whose color most tends to make them inconspicuous, but it does not account for the diversity of coloring in the first place. Without doubt the plastic tissues of the organism are directly affected by the reflections of light from their surroundings. In some cases, especially among the lowest, it is a mere matter of food. A worm consisting of a transparent skin, stuffed with green food, might easily be green, and a medusa composed of 99 per cent clear water, might easily be transparent, while another, living on muddy water, might have a muddy hue. But the color of the white bear, and the winter bleaching of rabbits, and other animals, must be due to the influence of prevailing colors in their environment.

At the same time we must not lose sight of the fact that where the coloring of the environment consists largely of color in plants, that circumstance shows that something in *their* environment colors *them*; and we may suppose that what colors them, might also give animals *their* color. Of course the animal is plastic as well as the vegetable, and affected by the same phases of energy. The vegetable is, however, first in point of time and so must contribute to the influences which operate on the animal. Where all light is excluded, organic tissues are apt to be white or light colored. Plants raised in the dark are colorless, and in colored animals those parts which are most sheltered from the rays of the sun are apt to remain uncolored. This is the case with fish which are colored on the back but white on the belly; also deer and antelope.

in addition are also white under their tails. The bleaching of the skin of northern races of men may be due in some degree to their wearing clothes. This conjecture is confirmed by the fact that the protean salamanders found in the underground lakes of Carniola, besides being destitute of eyes, are nearly white. If exposed to light they seem to suffer, and their skin seems to become colored. They are undoubtedly from a colored ancestry and have been bleached by seclusion.

CHAPTER XLV.

TOUCH.

The earliest, most common, indeed *the* universal sense is the sense of touch, including under this head the various subdivisions of the sense that depend on the stimulation of the skin. Every animal in existence, and some plants, possess this sense, which cannot be said of any other sense; and from it every other sense has been differentiated. It is no more inevitable that an animal should possess an outside, than that the outside should constantly come into contact with and be stimulated by objects external to itself, that is, its environment. It is the essential characteristic of protoplasm, as well as its products, to become more yielding and pliant to a stimulus that is able to move it without violence, the oftener and more habitually the stimulus acts; while, if the stimulus is violent without being destructive, excessive tissue is deposited at the stimulated point, the part hardens and its sensitiveness is lessened. The whole external part of the animal body is constantly in contact with some object—the ground, the air or the water. And in the course of its locomotion it may meet with and be arrested by many obstacles. The stimulus of gentle contact begets sensitiveness in the parts stimulated. This is first alike over the whole body in the case of simple aquatic animals. Later it becomes specialized in the projecting parts of of the body—limbs, tail and head. Later the limbs or their ends may through excessive stimulation become calloused and finally armed with nails or hoofs, &c., while the head with its appendages of snout, tongue or tentacles, &c., becomes more sensitive from the habit of more frequent stimulus of the proper degree of activity and force. Probably the general skin does not in any animal lose the whole of its sensitiveness, but it becomes *relatively* less in the skin in the ratio in which it is increased in special organs.

The skin consists of two principal layers. (1.) The epidermis, cuticle, or horn-plate, and (2) the dermis, corium, or true skin. This second bottom layer rests upon the cellular connective tissue which often con-

tains fat. It is the heavy part of the skin, that which becomes leather in the tanning process. The top surface of this layer is composed of a vast number of conical protuberances called papillae and tactile corpuscles. They rest on a bed of fibres which is closely interwoven like felt

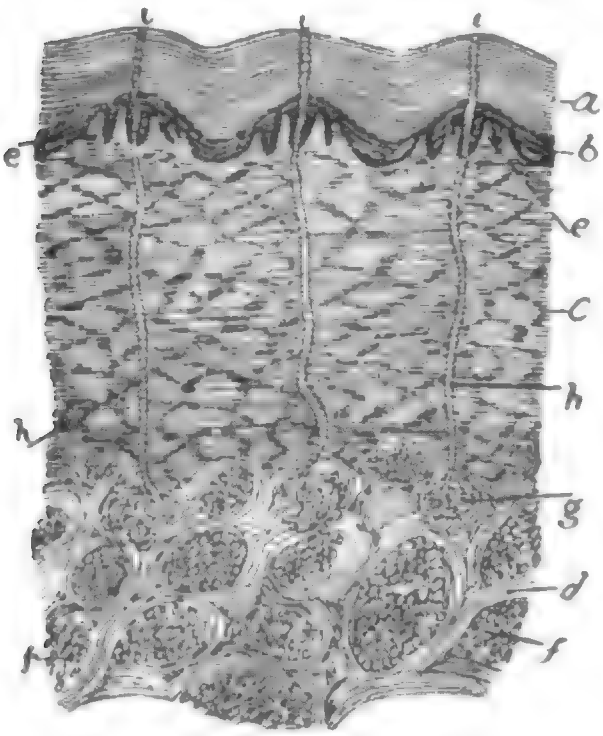


FIG. 166.

FIG. 166.—*Section of skin and subcutaneous tissue magnified 20 diameters.* (*Kolliker.*)
a.—Horny layer; Epidermis.
b.—Malpigian layer or rete mucosum, the pigment layer.
c.—Corium or true skin.
d.—Panniculus adiposus (fat layer.)
e.—Papillæ on the ridges of the corium.
f.—Fat clusters.
g.—Sweat glands.
h.—Sweat ducts.
i.—Openings of sweat ducts.

and of fine texture on the upper side next the papillae, but coarse and loose on the under side. Some of the fibres penetrate below into the fat and cellular tissue. The papillæ consist of an artery, a vein and a nerve, and are the terminations of the nerve connections between the skin and the brain.

The "tactile corpuscles" are formed in certain of the papillæ by an enlargement of the nerve into an oval swelling. The papillæ thus modified are formed only in the parts having the most delicate sense of

FIG. 167.—*Tactile Papilla* from the palm of the hand.
P.—Papilla.
C.—Touch Corpuscle.
N.—Nerve.
The touch papillæ are about 1-100 of an inch high and 1-250 of an inch in diameter.

FIG. 168.—*Pacinian Corpuscle.*
a.—Neurilemma—nerve cover.
b.—Nerve fibril.
c.—Capsule.
d.—Peculiar fibres.
e.—Central cylinder.
(*After Leydig.*)

touch, as the ends of the fingers, the hand and tip of the tongue, &c. There is still another class of sensitive bodies attached to some of the skin nerves. These are called Pacinian corpuscles, and are attached to the nerves of the sole of the foot and palm of the hand, and are found spar-

ingly in a dozen other places. In each corpuscle there is the termination of a nervous filament. Their uses are not known. (Med. Dictionary.) Underneath this sensitive layer imbedded in the corium is an abundant network of arteries, veins, nerves, and lymphatic vessels. These are all products by development of the corium or dermis. Besides these there are also imbedded in the corium, or below it, the sebaceous follicles (or suet bags), the perspiratory glands, the milk glands, the tear glands, the wax glands (of the ear) and the hair follicles; all of which originate by development from the epidermis or horn plate. They begin as ingrowths or projections from the epidermis, and penetrating inward, bury themselves in the corium or in some cases below it. In these positions they develop into their several varieties of glands or follicles and open their ducts through both layers of the skin to the surface. The ducts of the sebaceous or oil glands generally open into the hair follicles. The sweat ducts are very long, and much coiled at their lower ends and open by pores on the surface.

The epidermis, or horn plate, is composed of nucleated cells, which are formed at the bottom of the epidermis and in contact with the blood vessels of the corium, from which they receive their substance, furnished originally from the general circulation. They fill up the hollows between the papillæ. They increase their numbers by fission, and as they grow they make room by raising the cells above them. As layer after layer of these is pushed up they become flattened and hardened into scales of horn, which are constantly being worn off the outside of the skin. These lower live cells constitute what is sometimes called the mucous layer. Among these cells are to be found the pigment cells that give color to the skin when it has color, from which circumstance this layer is sometimes called the color stratum, or pigment layer.

The sense of touch, like every other sense, is the result of active movements, of some sort, in the environment. Without movement there is no sense. The movements concerned in this sense are friction, pressure and temperature. Some authors make a distinction between "touch" and "tact," regarding the former as an active sense residing in the active touch organs, fingers, tongue, &c., and the latter as a passive sense. This distinction is hardly proper, since all parts of the skin are sensitive, in some degree, to friction, temperature and pressure, and all parts are alike dormant and senseless when not under one or the other of these stimuli. If we put our hands in water warmed to their own temperature, and hold them still, we do not have any sense of touching the water. But if we move them, the friction conveys a sense of touch. We are not ordinarily conscious of touching the air, but if it move or we move in it, we feel the friction. If it be warmer or colder than our skin, we feel it through the sense of temperature. If our

clothes fit well and are not heavy, we may become quite unconscious of their contact with us. But if they press some spot, or cause too much warmth, we become conscious of the action of the senses of pressure and temperature. Many of the touch sensations are compound, involving some two of the three simple ones—as friction and pressure, friction and heat, pressure and heat—or all three. A stimulus may exhaust itself in the cuticle alone, and be propagated thence, through the nerves as nervous electricity, to the brain. If the stimulus is excessive, the excess, after exciting the different nerves, is expended on the papillary layer of the dermis, causing increased secretion from its blood vessels. Scalding heat causes an effusion of serum, which separates the dermis from the cuticle and makes a blister. Excessive pressure produces the same effect. The sensation in such cases is simply one of pain, which is the only sensation arising from the agitation of the nerves of the papillæ directly—they not being the organs of touch, but only the vehicles of the stimulating current. Gentle pressure, or the pressure of a soft body over a great surface of the skin, acting through the cuticle upon the papillary layer, is not painful unless protracted, but stimulates the vascular system of the dermis to supply more nourishment to the cells of the mucous layer of the epidermis—squeezes out the juice into the cuticle, as it were, and builds it up more rapidly, and so erects a barricade between the tender papillary layer and the pressing force outside. Thus originate the extra thicknesses of epidermis on the soles and palm, and the callosities formed in chance spots exposed to protracted pressure.

The different stimuli, friction, heat and pressure, when they are expended on the epidermis, are converted, in part, into afferent nerve currents, which affect the brain cells corresponding to touch sensation, and the rest raises the molecular action of the tissues of the skin and adjacent parts, giving an increase of temperature, which, if strong enough, also produces a sensation in the brain. Evidently, different sets of nerve fibres must be devoted to the carrying of the different sorts of sensations. In the case of the eye we shall see that there are various sets of rods and cones to convey the stimuli of the various light rays composing the spectrum, that we can perceive. Radiant heat is governed by the same laws as light, consisting simply of lower tones of the same radiant energy. Analogy would lead us to suspect that the organs of heat sensation might be constructed on the same plan—a different set of organs for different rates of radiant vibration. But it appears to be not so. For all the rays of heat appear to our consciousness as of the same quality; as if the wave lengths were all the same, and the differences consisted only in amplitude or intensity. But although the energy of the dark radiation, or heat, of an incandescent

body is about eight times as great as the heat energy of the visible radiation, the thermo-electric pile shows that in no two spots of the spectrum is it the same in energy, and the fact that the length of the invisible part of the spectrum is almost double that of the colored part, shows that the wave length of the invisible rays regularly increases, and the capacity for refraction as regularly decreases with the distance (downward) from the red end of the color spectrum. Now, it is evident that the skin is sensitive to the energy of all the rays of the dark part of the spectrum, and a good many of those in the color part of it also, regardless of their greatly differing refracting capacities.

Each of the minute optic organs situated upon the retina is competent to receive and transmit a stimulation from only a single radiant ray, but the sensation produced in the brain by that rendering is inconceivably different from another rendering of the very same ray which may be made by the skin. We find here an illustration of the difference in the result of the action of an external stimulus upon a completely differentiated organ, as compared with the action of the same stimulus upon an organ not specialized. The skin is the unspecialized organ, and according to the laws of differentiation it responds in an indifferent manner (comparatively) to a vast number of phases of radiant stimulation. The little optic organ is a highly specialized piece of that very skin, differentiated to respond to a single one of the many stimuli that constantly beat on the great unspecialized skin. These terms, however, are only comparative. Our skin *is* specialized and can be set in motion by several octaves of radiant energy. It is evident that the various heat stimuli, striking upon the skin, are elaborated by it, all reduced to a common form and projected upon the brain as a uniform sensation varying only in intensity. This quality which I infer resides in the skin, calls to mind that property of certain substances, which is called *fluorescence*, by which the high rate vibrations of the rays *above* the color spectrum are reduced to rates which render them visible. (See chap. 41.) From whatever cause it may come, we are forced to the conclusion that the skin is the common organ for a wide range of tones of heat, and the probability that its composition may include constituents able to equalize these tones, affords a satisfactory explanation. In regard to the other two methods of stimulation, viz., friction and pressure, it appears probable that separate papillæ and nerve connections are devoted to each. The epidermis is the common organ in which the external stimulus is arrested and reduced to one of three modes or tones of nervous electrical motion. Each tone flows to its own differentiated vehicle and reaches its own corresponding brain cells, the erethism of which completes the sensation. That is, the waves of ether arrested by the skin become current motion up the different nerves to the brain cell, where such motion ceasing, it is

succeeded by a motion of brain cells called sensation of heat. The researches of Blix and Goldschneider appear to show that changes of pressure and of warm and cold temperature are perceived through different points of the skin. "The feeling of pressure seems to be intimately associated with the hairs, which is not the case with sensations of temperature. These three sets of points indeed are so near together that the separation had hitherto not been observed, especially as they are so closely intermixed." "Goldschneider experimented with a fine point which he passed over the skin, thus testing it, sometimes for pressure, sometimes with a warm point for heat, sometimes with a cold point for cold. Moreover, if he raised the points of skin thus determined, with a fine needle, and snipped off the fragment of the skin, he found that the resulting sensation was quite different in the three cases. If the point removed was a pressure point, the sensation was one for the moment of pain, while the temperature points gave sensations respectively of *heat* or *cold*. The terminations of the temperature nerves are, according to Goldschneider, much finer than those of the pressure nerves, and they are also fewer in number. He cut from his own skin a large number of sensitive points, but while he found that each corresponded to a nerve end, he was not able to discover any difference at or in the termination of the nerves corresponding to these different sensations, though it may reasonably be expected that such must exist. The question has arisen whether there are separate nerve endings for pain as apart from pressure, &c., but the observations of Blix and Goldschneider appear to show that pain arises merely from the intensification of other impressions and that it does not reside in any special organs."[1]

These researches of Blix and Goldschneider seem to show a differentiation of the temperature-points of the skin into two classes—one class

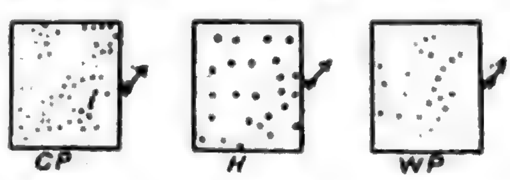


Fig. 169.

Fig. 169.—*A patch of skin on the back of the hand* showing position of points of sensation.
C P.—Points sensitive to cold.
W P.—Points in same patch sensitive to warmth.
H.—Position of Hairs, the points sensitive to pressure. (*After Blix and Goldschneider.*

sensitive to *warm* stimulations and the other sensitive to *cold* stimulations—by which I understand stimulations above and below the ordinary temperature of the body. The three square figures illustrate this, CP showing the points on a single patch of the back of the hand irritated by the cold stimuli; WP, those affected by the warm stimuli, while H shows the position of the hairs on the same patch. It may be that it is the stimulation of the "cold points" which is transferred to the little muscles of the hair follicles causing the phenomenon of "horripilation," or goose skin, these points being movable only by the heavy long waves of very low temperature. (See chapter on Emotion.)

[1] Lubbock Animal Senses, p. 10.

The sensibility of the skin in different parts varies greatly, and the number of the tactile papillæ is much greater in some parts than others. Another peculiar circumstance is, that although every particle of the surface of the skin can convey to the brain the stimulation of touch, it does not convey an impression of its exact locality. If a pair of dividers with blunted points, spread apart to a distance of say half an inch, be applied to certain parts of the skin so that both points touch the skin at the same time, the person touched will feel the two as only one. The entire skin may be divided into circles of various sizes within which two or more simultaneous stimulations of the skin will be felt as only one. The body has been gauged all over with dividers and the sizes of these circles determined They are smallest in the tip of the tongue and the tips of the fingers, the parts most used in touching.

The following is a table of the smallest distances apart of the legs of the dividers at which they were felt to be distinct from one another. The figures are lines, twelfths of an inch :

Point of tongue	½	Gums	9
Inner face, middle finger	1	Lower part of forehead	10
" " index "	2	Neck below the jaw	15
Lips, red part	2	Skin over lower back bone	18
Palm of hand	3	Top of foot	18
Tip of nose	3	Skin over breast bone	20
Edge and top of tongue	4	Middle of back	30
Cheek	5	" " arm	30
End of big toe	5	" " thigh	30
Back of hand	8		

Thus it appears that the parts most active in touching are the most sensitive; which, of course, was to be expected. The parts least sensitive are those least exposed to touch stimulations ; and it is curious to observe the increase of sensitiveness as the chief centers of stimulation are approached. If the points of the dividers are separated to 6 or 8 lines, and placed on the cheek near the ear, they will be recognized as being barely distinct. If they are then drawn slowly toward the lips, they will give the impression that they are getting further apart as they advance; for the reason that they are moving from larger to smaller circles, that is, into a more sensitive tract. The same sensation is experienced when the points are placed across the fore-arm and drawn down the arm and hand to the tips of the fingers. In the middle of the back the points must be two and a half inches apart before they are each able to give a sensation independent of the other. We shall see further on that all parts of the body are represented in the brain. One portion of the brain receives the stimulations of sight, another of hearing, a third of touch, &c., and every cell of the brain is connected by a nerve fibre with its own definite part of the body. But it does not follow that every *cell* in the body has its corresponding brain cell;

there are not enough brain cells to admit of that. But it must be that in the case of touch, a single brain cell receives all the stimulations that are made on a definite portion of the skin, the size of which depends wholly on the general average amount of the business done. Thus on the back, which receives but few stimulations, a single brain cell gathers all that occur in a circle two and a half inches across; while the amount of business at the tip of the tongue is great enough to require at the rate of 3600 times as many cells for an equivalent area, that is, the circles served by a single cell are only $\frac{1}{3600}$ as large. When a stimulation is made, the brain can probably locate the circle in which it is made, but not the particular part of the circle; and so, if the two points both touch at once, it gives the impression of only one. But it is obvious that if the circles are bounded by definite lines, the two points, when tolerably close together, might straddle a line, and so it would seem ought to give two impressions, which they do not do. The reason of this is not settled. But it must be that when an impression is made anywhere on the skin, the stimulation instantly spreads in all directions through the cells of the skin, until a nerve fibre is reached which leads to the brain. Without doubt, the skin cells are organs, in which the forms of motion, such as pressure, friction, &c., are changed to the nervous current, and there are probably no boundaries of circles so rigidly defined that the stimulation cannot spread through the skin laterally. Suppose *a* and *b*, fig. 170, to be the two points of the dividers, at a distance apart less than the diameter of a sensory circle—each point being in a different sensory circle. The irritation spreading from both in all directions, will overlap and reinforce each other at *c*. This point lies in the same sensory circle as either *a* or *b*, and its stimulation will reinforce that of the point lying in the same circle. In other words, the stimulation will be made up at last in favor of the sensory circle in which the most of the stimulation lies, considering the two stimuli together. But there is a residual fraction of stimulation left in the other sensory circle, presumably not enough to excite the brain cell, but which might come to have power to do so after considerable practice.

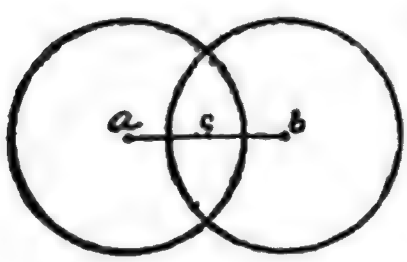


FIG. 170.

Bernstein, in his "Five Senses," says: "Upon the same spot of skin, the size of a sensory circle not only differs in different people, but varies considerably in the same person at different times. The most interesting fact, however, is that *constant practice considerably diminishes* the limit within which a single impression is produced in certain parts of the skin, in those parts, for instance, which are not naturally very sensitive, and where the sensory circles are large. If, however,

this practice ceases, the delicacy of the sense of touch will decrease also." The sensory circles of the blind are also smaller than of other people—due to practice.

The sense of touch is liable to many illusions which have to be corrected by other senses. But if the other senses are not available for the purpose, as in the case of the blind, touch becomes exceedingly intelligent. The well known illusion resulting from crossing the fingers and placing a pea, or other small, round object between the ends, so that it touches the left side of one finger and the right side of the other, is due to the want of habit in those parts of the fingers of touching a single object of that shape simultaneously. It "shows how firmly the representation of the surface of our body is imprinted upon our brain," for the brain, receiving its accustomed sensation from the parts, adopts also its accustomed perception of the facts, although false, unless it is modified and corrected by another sense.

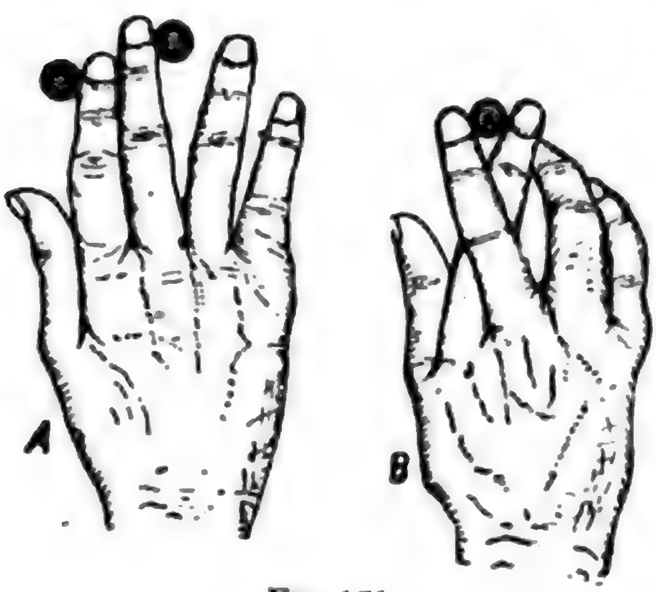


FIG. 171.

FIG. 171.—*Illusion of the Sense of Touch.* In the unaccustomed position of the fingers in B, a *single* ball gives the two separate stimulations which it requires *two* balls to give when the fingers are in their habitual position, as in A.

Muscular Sense. Besides the sense or senses belonging to the skin, there is another, called the *muscular sense*, which appears to have its seat and organ in the muscles. This is the sense of resistance to muscular effort. Thus, if a weight is lifted, besides the sense of pressure, which the skin conveys to us, is that sense of the amount of the weight which we will have independently of the pressure sense; for the pressure on the skin of a two-pound weight will be no greater than that of one pound, if it be shaped to cover double the surface; while the muscle will easily feel the difference. The muscular strain may depend on any other cause as well as gravity, but the principle is the same, and the strain may be expressed in terms of gravity, as it generally is in mechanics. Like everything else in organic structure, this sense is increased in mobility by use; in other words, improved by habit, and often becomes very delicate in persons accustomed to handle things and sell by weight. This sense is not to be confounded with the feeling of fatigue which follows exhaustive effort, and which is a subjective sensation, because it furnishes us with no information of objects *outside* of ourselves, but only of a state existing within us; while a true sense is an organ used and operated by an external energy. The sense of

pressure and the muscular sense almost always accompany each other, because they are almost always exercised by the same act. The *absolute* sense of pressure is very vague, because it depends so much on the surface covered by the weight. The body lifted always seems heavier if the part by which we hold it presses upon a smaller surface of skin. E. H. Weber's experiments showed that when both muscle sense and pressure sense were combined in lifting a weight, a difference could be felt between $19\frac{1}{2}$ and 20 oz., or one fortieth, or the addition of $\frac{1}{39}$. But where a weight was laid upon the skin so as not to call upon muscular exertion, only the difference between $14\frac{1}{2}$ and 15 ounces could be perceived, or the addition of $\frac{1}{29}$; the same proportion held for other weights. The perception of differences depended upon the rapid succession of their application, one after the other. The memory could not hold the first weight more than 10 seconds. After 30 seconds between the application of the weights the sense could not discriminate if the difference were less than $\frac{1}{5}$ of the first weight. The sense or memory of the impression vanishes thus rapidly from the brain. This could, no doubt, be improved by practice. The sense of pressure does not accompany the delicacy of the sense of touch. The skin of the forehead and stomach have a delicate sense of pressure, but only a dull sense of locality.

Our sense of temperature is entirely relative; we call a thing warm which transfers heat to us, and cold which conducts it away. Of two objects of the same temperature, we call one warm and the other cold.

Weber found that with the finger he could perceive a difference when it amounted to half a degree Fahrenheit, and this proportion of relative difference could be discovered up to blood heat. The sensitiveness of different parts depends largely upon the thickness of the skin, the thin skin being the most sensitive, for the obvious reason above adverted to, that the extra thickness of skin is in the horny, nerveless scales of the epidermis, built in front of the nerve-bearing papillæ by *excessive* stimuli for their own use—the use, that is, of the excessive stimuli. So that the cuticle in such parts is no longer so easily affected by moderate stimuli. The back of the hand, elbow, eyelids, lips and tongue, are the most sensitive. Weber found that warm bodies appear lighter than cold ones. A cold coin placed upon the forehead appeared as heavy as two warm ones afterward placed on the same spot; as if the contraction or *pressing together* of the epidermal cells, in consequence of the coldness communicated from one coin, was equal to the pressing together of the same cells by their weight.

There is probably no animal, however small or simple, that is destitute of the sense of touch. The jelly-fishes, Medusæ, have long tentacles, very sensitive, which contract from a slight touch. Some species have tactile hairs on the margin of their umbrella-like bodies. These

seem to be specialized organs. Star-fishes and Echinoderms also have similar tactile organs. Earth-worms are very sensitive to contact, the

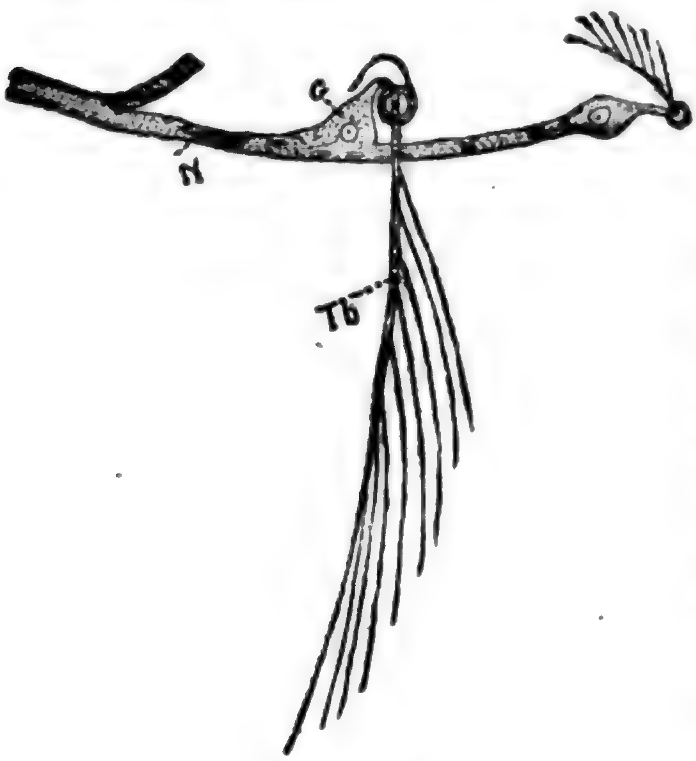


FIG. 172.—*Tactile apparatus* from the skin of larva of *Corethra* (a two-winged insect of the gnat form).
Tb.—Tactile bristle.
N.—Nerve.
G.—Ganglion.

FIG. 172.

whole skin being an organ of touch. As a rule, the animals above the worms are all sensitive to touch on the exposed parts of the body, and generally they have specialized organs for purposive touch. Crustaceans and Articulates generally have long tactile bristles. When a bristle is touched, it vibrates down to its roots, where it connects with a nerve fibre and transfers the stimulation to it.

In the Cuttle fishes, Octopus, &c., the long tentacles are very delicate organs of touch. In the mammals, the snout, including tongue, &c., is specialized into a touch organ, and many, such as Squirrels, Bears, Monkeys, &c., have the touch sense specialized in their hands. The wing of the Bat has become exquisitely sensitive to varying pressure in the air as shown by its avoidance of obstructions in its rapid flight, even

FIG. 173.—*Organ of Touch of Onchidium.* Diagrammatic section. (*After Semper.*)
a' a''.—Two layers of the cuticle.
a.—A biconvex thickened portion of the cuticle.
b.—Enlarged epithelial cells.
b'.—Ordinary epithelial cells.
c.—Cellular body.
d.—Cells.
n.—Nerve.

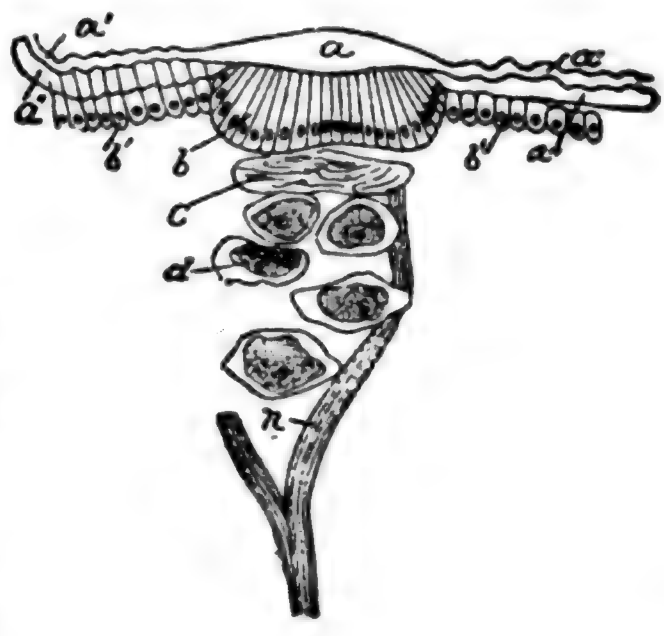


FIG. 173.

when made blind. There is a naked mollusk living on the shores of some tropical seas called the Onchidium, which possesses some remarkable sense organs both of touch and sight. The organ of touch is shown in fig. 173. It is strikingly like a simple eye and carries a suggestion of an easy possibility of being developed into one. (See figs. 183, 184.)

The tactile papillæ which are common to the vertebrates are not found in the invertebrates. In Lizzards they occur under the toes. In the chameleons and some ant-eaters the *tail* is the organ of touch and con-

tains the papillæ. The frog has them for a *short time only* in the spring in his swollen thumb. (See page 124.) In birds they are in the toes, or the web if they be web-footed. In the cat, &c., they are at the roots of the whiskers. In the mole they are on the tip of the snout; and in the elephant and tapir, on the trunk. In monkeys they are in the hands and sometimes the tail. They are by no means all over the human body, and many papillæ are destitute of nerves, as are even some of those in the palm of the hand.

CHAPTER XLVI.

SIGHT, AND THE EYE.

In tracing the comparative anatomy of the eye, we find that the first visible sign of such an organ in the lowest of animal life is a pigment spot, which is in direct contact with a nerve, and forms through it a connection with other nerves which control the action of some muscle or motor organ.

An undifferentiated skin, if such a thing were possible, when subject to the impact of various tones of energy, is brought into various degrees of harmony with them. The tones of the impacts on all bodies are in great variety, consisting of all the rates of vibration, from the very first octave which gives the sensation of sound, up to the forty-fourth, which gives the sensation of light. It is quite certain that the constitution of protoplasm is such that some of the tones in every octave are competent to set its molecules or molecular spaces into vibration. If a body having a certain fundamental pitch be agitated by a force tuned in unison, it will be set to vibrating in tune; but if the agitating force be not in unison, it will simply cause a jar or shock in the receiving body, and not a rhythmical vibration. The first nine octaves have found elements in organic protoplasm that can be vibrated in unison with most of the tones in those octaves in the production of sound. But it would seem that the tones of vibration from the 10th to the 43d, inclusive, have not yet been able to set up *rhythmic* vibrations in an animal body. They fall upon it in a promiscuous and helter skelter fashion, interfering, no doubt, with each other, and producing in the animal an undifferentiated sensation of heat. If some certain predominant or specially suited tone of one of these octaves, could have its way with the animal body without interference from other tones, there is no reason to doubt that the part of the body subject to the impact of such tone would become differentiated to respond to it rhythmically, and thus a new sense be created. If one big dog trots across a light truss bridge, he will throw it into a vibration in tune with the movement of

his feet. But if a dozen dogs trot across, they will jar the bridge but not set up in it a rhythmic vibration, because their untimed movements neutralize each other.

A *few of the tones* of the 44th octave have been under conditions which allowed them to produce the rhythmic motion required for this differentiation, and the result is the sense of sight. The whole of the skin or outside of animals has been subjected to the many tones of heat vibrations, and the many sorts of shocks from touch and pressure, until it has acquired a sensitiveness or aptitude for being shocked and jarred in a great many different ways. This sensitiveness is transmitted by heredity from one generation to another, and each generation by its habits produces temporary modifications which imitate differentiated senses, to a certain degree. An infant gets an abstract sensation by touching an object, but it requires repeated experience to be able to distinguish various sorts of touch. But we soon acquire a sense of touch for glass, another for iron, another for wood, another for cloth, &c., and great refinements of the sense are attained in special directions, as by the dealers in woolen fabrics in judging the qualities of the goods. The sense of touch is then a very educable sense, and the skin as its organ is easily subject to various modifications. Accordingly, we find that all the sense organs are developed from the skin. The pituitary membrane of the nose, the organ of smell, and the linings of the ear sacs, the organs of hearing, are modified portions of the outside skin punched in by invagination. The retina, the sensitive organ of sight, is formed in the vertebrates by a portion of brain punched out, but the brain is itself a derivative of the skin layer, so that the organ of sight is no exception to the rule. This derivation is more readily seen in some of the lower animals in which the development is shorter and more direct.

The sense of sight, then, is the result of a modification of a portion of the skin by the impact of the ether waves of the 44th octave. As said above, the first visible indication that a portion of the skin has undergone a special modification, is usually a pigment spot. It is not always certain what sense is represented in the pigment spot in the lowest animals, as an organ of hearing or of smell may begin in a similar modification. But it is settled in very many cases that the pigment spot is an incipient eye. The effect of the light upon the place first alters the secretions and induces the deposit of the pigment, and this deposit in turn instantly becomes a factor in selecting the tones of vibration by which the organism will be chiefly affected. For of course every sort of pigment has the power to absorb certain tones of the radiant vibration, and thus to sift and separate the rays, leaving those of suitable pitch free to get in their influence on the organism without interference or loss.

The comparative anatomy of the eye will be discussed in the next chapter. The human eye is among the best and in some respects is probably the best developed mammal eye. A general description of this eye will serve as a basis of comparison for eyes in general. The eyeball is enclosed on the outside by a tough coat called the sclerotic. The greater part of it is white and opaque, but in the front part of the ball it becomes transparent, and bulges out with a shorter radius than behind and is therefore more convex. This transparent and more convex part is called the cornea. Inside the sclerotic, and lining it, is a vascular membrane called the choroid. The inner layer of this membrane is composed of pigment cells of black color. In the front part of the ball the choroid coat is puckered into about sixty longitudinal ridges which are called

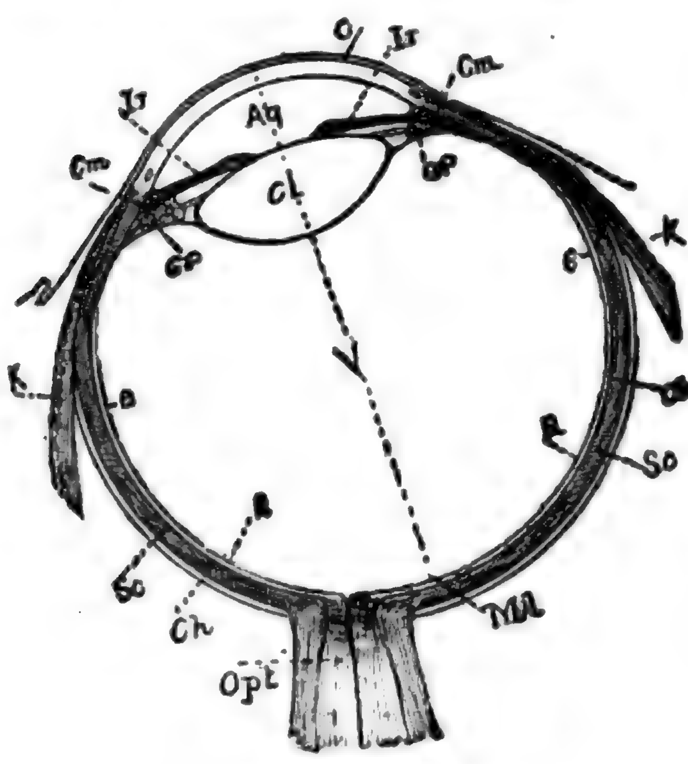


FIG. 174.

FIG. 174.—*Section of Human Eye.*
C.—Cornea.
Ir.—Iris.
Aq.—Aqueous Humor.
Cm.—Ciliary Muscle.
C P.—Ciliary Process of the Choroid Coat.
C L.—Crystalline Lens.
V.—Vitreous Humor.
K.—Recti Muscle.
R.—Retina.
e.—Anterior limit of Retina
Sc.—Sclerotic Coat.
Ch.—Choroid Coat.
Ml.—Yellow Spot.
Opt.—Optic Nerve.

the ciliary processes. In front of and lapping over the ciliary processes as if they belonged to an outside layer of the choroid, is a layer of muscular fibres attached in the rear to the choroid and in front to the inside of the sclerotic, so that their contraction tends to pull the choroid forward. Attached to the ciliary process is what is called the ciliary zone or suspensory ligament of the lens. This is in the shape of a ring, the outer edge being attached to the ciliary processes and the inner edge to the crystalline lens. In shape the lens is convex both in front and rear, but more so in the rear. It does not touch the cornea in front, but is separated from it by a space filled with a transparent albuminous fluid having a little greater density than water and called the aqueous humor. Attached to the sclerotic at the margin where that coat merges into the cornea, and where also the anterior ends of the ciliary process are attached, is the outer margin of the circular curtain or diaphragm called the iris. This is colored, and gives the eye its blue, brown, gray, black &c., appearance. It has a hole in the center called the pupil, which appears black on account of the background of black pigment in the choroid coat. The iris automatically contracts or expands in the pres-

ence or absence of light, thereby enlarging or diminishing the pupil. Inside of and lining the choroid coat of the eye is the third coat called the Retina. It varies in thickness from $\frac{1}{80}$ to $\frac{1}{160}$ of an inch and consists of nine layers as shown in fig. 176. The center of the eyeball is filled with a transparent fluid of albuminous matter something like the aqueous humor, but denser. It is bounded in front by the crystalline lens and on the sides and rear by the retina. The aqueous humor is secreted from a thin membrane which lines the cornea and which repairs any of its losses. But the vitreous humor is not so repaired and if lost the eye is permanently destroyed. The crystalline lens is made up of a series of concentric coats and is more dense than either the fluid in front or that behind it. In the disease called cataract, an opaque matter is in-

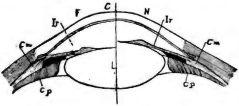


Fig. 175.—*Front of Eye Showing Adjustment of Lens for Far and Near Objects.*
C.—Cornea. *L.*—Lens. *Ir.*—Iris.
N.—Adjustment for Near Objects. *F.*—Adjustment for Far Objects.
Cm.—Ciliary Muscle or Choroid Stretcher, which by contracting pulls forward the Choroid and allows the Lens to thicken.
Cp.—Ciliary Process of the Choroid.

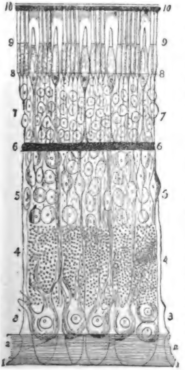


Fig. 176.

Fig. 176.—*Section of Retina greatly magnified.* (*After Max Shultze.*)
1.—Fine Limitary Membrane the *inner surface of* Retina.
2.—Layer of Nerve fibres.
3.—Nerve Cells similar to those of the Brain.
4.—Granular Layer; a fine, gray, indistinct mass.
5.—Granular Layer of round, small grains.
6.—Granular Layer of small grains mixed with fibres.
7.—Outer Granular Layer; like number five.
8.—A Fine Membrane.
9. Layer of transparent *Rods and Cones.*
10.—Choroid Coat of black pigment.
The light strikes on No. 1 and passes through all the layers up to No. 9. The thickness of the whole Retina is from 1-160 to 1-80 of an inch.

fused into the substance of the lens hardening and making it impervious to the light. The lens may be removed and if the vitreous humor is not disturbed, the loss of the lens may be compensated by the use of spectacles of very short focal distance. The convexity of the lens is altered automatically to adjust its focus to objects at different distances. It is supposed that the suspensory ligament of the lens habitually pulling it by the outer edge tends to flatten it against its natural elasticity so that it is focused ordinarily for long distances. When near objects are to be seen, the ciliary muscle comes into play, and by its contraction the choroid is pulled forward and the suspensory ligament with it, by the relaxation of which the lens is allowed to draw in its edges and increase its convexity in front and so shorten its focal distance. (See fig. 175.)

The retina of the eye is the part in which the wave movements of the ether are converted into nervous energy and transmitted through the optic nerve to the interior parts of the body and especially to the brain, in which alone the sensation of light arises. Of the nine layers of the retina only one—the outside one next the choroid coat—appears to be directly concerned in this process of converting the waves, the other layers being chiefly accessory parts for the propagation or transmission of the new nervous stimuli. This outside layer constitutes about one-fourth of the total thickness of the retina and is called the layer of the rods and cones. The rods and cones are of the shape implied by their names, and standing in a dense multitude on the fine membrane marked 8 in Fig. 176, point outward in a direction parallel with the radius of the eyeball toward the choroid coat. Beginning at the inner ends of the rods and cones a great number of delicate nerve fibres pass inward, spread out into branches and traverse the other layers to the inside limitary membrane. Next to the limitary membrane is a layer of nerve fibres, subdivisions of the optic nerve (No. 2). Outside of this is a layer of ganglionic corpuscles (No. 3) with which the fibres of the optic nerve freely communicate, as also do the radial fibres from the rods and cones. Nos. 4, 5, 6 and 7 are layers of granular matter of differing consistencies, 4 and 6 being finely subdivided, while 5 and 7 are of larger granulations. The blood-vessels of the retina lie between No. 5 and the limiting membrane.

The light, in passing to the rods and cones, must therefore go through the tracts holding the fibres of the optic nerve and the blood vessels. As the rods and cones are the essential organs of sight, they can see the blood vessels just in front of them, as may be proved by an experiment which is performed in a dark room with a dark wall and a single candle. Look toward the dark wall steadily, and move the light to and fro past the eyes, and so as to shine into them—or one of them—obliquely, and after a little practice it is possible to see the red intersecting lines of the

blood vessels. This goes to prove that the optic nerve itself is not the organ of sight, since its fibres are mingled freely with the blood vessels. But this fact is still better proved by the blind spot. This spot is between the center of the retina and the nose, and is the place where the optic nerve passes through the sclerotic and choroid coats of the eye and the outer layers of the retina itself. After passing these it spreads to left and right, ramifying all through the inner layers of the retina, as stated. An image thrown upon this spot cannot be seen, as a simple experiment will prove. Thus, fix the right eye on a distant object and hold the end of the finger, or other small object, in front of the nose ten inches away. Now move the object to the right three to four inches, and it will become invisible, but after going further to the right it comes into view again. This blind spot is the bundle of the optic nerve fibres, and there are no rods or cones mingled with it in this place.

Directly opposite the pupil on the retina is a round spot called the *macula lutea*, or yellow spot, so called from its color. This spot is the area of the greatest visual power, and whenever exact and clear sight is required, the eye is automatically turned so that the image of the object is thrown upon it. It is more densely packed with cones than any other part of the retina, and they are longer than elsewhere, while the rods are absent. The other layers over this spot are very thin, and around it the nerve fibres are very abundant. Outside of the yellow spot the rods appear among the cones, and increase in number till at the edge of vision they are three times as numerous as the cones, and the latter decrease in length as they diminish in number. To Max Shultze belongs the credit of having discovered that the function of the rods is the sensation of light as distinguished from darkness merely, but that of the cones is the sensation of color, or of one kind of light as distinguished from another. In the yellow spot, therefore, all the colors are perceived. But as objects are passed to one side so as to be seen by the edge of the retina, the power to distinguish color is lost before the power of distinguishing forms. First, we become blind to red, later to green, while yellow and blue are distinguished well out upon the edge of the retina. On the other hand, it is shown that the region of the yellow spot is not so acute in distinguishing faint light as the tract of rods outside of it. This can be tested from within a dark room by turning the eye toward a window that admits a very faint light. The light will be seen better by the side of the retina than by its center.[1]

Now, if it is true that the action of light is the cause of the habit by which the modification and evolution of the eye has taken place, it would follow that the tissues of the rods and cones must become ex-

[1] Henry T. Fink in Lit. Liv. Age, Vol. 144, page 25. Probably this differs with different individuals.

hausted and disintegrated by the light, and renewed by fresh accessions of organic matter from the blood. The proof of exhaustion of any of the tissues comes with the fact of such tissues losing their mobility under their usual stimulus. Such mobility is lost for all the rods and cones after a short exposure to direct sunlight or electric light, and this means total blindness for the time. A brief period of rest in darkness allows the blood vessels of the retina to replace the wasted tissues and restore their mobility. If the eye be allowed to rest upon a colored spot, as a red wafer, for example, until fatigued, and the vision then transferred suddenly to a piece of white paper, a spot the size of the wafer will appear on the paper, but it will be greenish instead of red. And generally, when the eye is exhausted by looking at one color, upon looking at a white object an image of the same form but of the complementary color will be seen. This proves that some of the cones are sensitive to one sort of rays, while mingled with them are others sensitive only to other rays. Thus, if all the cones in the tract covered by the image of the wafer on the retina were alike, they would all be fatigued, and when turned to look at white paper would see a black spot instead of a green one. But only those sensitive to red being fatigued, the rest are able to see their several colors reflected from the white sheet, the resultant of their mixture being green. Outside of the spot, all the cones being fresh, all the white will be seen, because each cone is agitated by its own ray, and the complete union of all the color sensations is the sensation of white. It is not necessary to infer from this that there are cones for every possible shade of color, or for every shade of color that we can recognize. White light can be produced by the combination of red, green and violet, and by unequal combinations of these three, or of two of them, every possible shade of color may be produced. Based on this fact, a theory has been proposed by Thos. Young, and accepted by Helmholtz and others, that there are three kinds of cones susceptible to these three colors severally, and that their agitation in varying degrees produces, when the sensations are intermingled, a sense of some one of the thousand possible shades.

Thus, yellow light shining into the eye would agitate strongly the cones sensitive to red and green, and slightly those sensitive to violet. The several agitations thus derived from one ray would produce in the brain the single sensation of yellow after the reconsolidation and mixture of the three. In whatever manner any shade of color should be broken up in contact with these three kinds of cones, when the three sensations caused by them are thrown together they will reproduce some sort of a sensation of that shade of color. Such sensation would probably be uniform for each individual, but might not be the same for any two. Indeed, we have no means of knowing whether the sensation

formed by a color, or anything else, for that matter, is the same in one person that it is in another. An individual having received a sensation which he calls yellow, after the instruction of others, will compare succeeding sensations with the first, and name them yellow or otherwise, as they appear to agree or not.

I think, however, if the probable evolution of the cones be considered, we shall find reason to modify Young's theory somewhat. First, we must distinguish between a simple color and a compound color, which may, with propriety, be designated, respectively, a true and a false color. The first is the objective impression of waves of a particular and uniform length, and is the color as expressed in the solar spectrum. The second arises as the resultant of two sensations, one above and the other below the true color. If an inch be divided into one hundred million parts, the length of a wave of middle yellow light from the sun would be represented, according to our table in chapter 40, by 2172 parts. But the sensation which waves of this length gives, can be approximately counterfeited by the simultaneous action of the red and green rays, respectively, 2441 and 2016 parts long, the average of these figures being 2228—a dark shade of yellow. Now, if we suppose the cones to be differentiated from the rods by the action of the various waves, it is conceivable that according to Young's theory we should indeed get the sensation of yellow from the joint action of red and green, because there would be cones susceptible to red, and others susceptible to green agitations; but if a ray of pure solar yellow light should strike these cones they ought not to be affected, and there being no cones differentiated to the action of waves of 2172 parts, the eye would be blind to this true yellow, while it could see the false or compound. If it be said that the three kinds of cones can be agitated by the waves of different lengths, then why suppose three sorts of cones? Perhaps there are only two—or even only one. But the experiments showing fatigue by looking at one color, while the eye is fresh for other colors, prove the cones to be several kinds, and if that is so, each kind must have been so developed by the action of one simple kind of light. We might reasonably suppose that the colors most predominant in nature would be the ones to make their mark on the plastic organism, such as the blue of the sky and the green of the foliage, &c. The blue of the sky is probably a simple color, being the refraction from fine particles of matter suspended in the air, or from the molecules of the air itself, of a diameter equal to the length of blue waves. But, as we have seen, there is reason to think that the green of chlorophyl is compounded of yellow and blue, the green seen in foliage, or at least much of it, would tend to develop in the eye not green seeing cones but yellow and blue ones. It is said that five per cent. of Europeans and European-Americans are

color blind. This is a defect that extends to red and green only, or chiefly. Color blind people, as a rule, have no trouble with yellow, blue and violet. This fact indicates that these latter colors are of earlier evolution in the race history, and are therefore faster colors. As we have observed, of all the parts subject to evolution by habit, the older the habit, as long as it is active, the less is the liability to reversion and loss of function. Again, if we have but three kinds of cones, one for violet and the other two for seeing red and green, color blind people could get no idea at all of yellow; whereas, the fact is, the sense of yellow survives when red and green have become reversions. I have spoken of the rods as having the sensibility to light as contrasted with darkness.

As the lower octaves of the vibrations of the ether produce upon animal and vegetable protoplasm and tissue a peculiar molecular movement, and the sensation of heat in degrees of varying intensity, so the 44th octave as a whole produces other peculiar movements, and the peculiar subjective sensation of light. Some kinds of organic tissues are more influenced by one part of this octave and some by another.

It is the general influence of the various vibrations of the octave that together give the sensation of light, and differentiate the rods from the nervous tissues of the retina to respond to these general mixed vibrations. By the law of differentiation, as explained elsewhere, organs or parts subjected to various movements under varying stimuli do not respond perfectly to any one. As long as the stimulus is compound the response is imperfect and uncertain, and it is only when the compound stimulus is split up into simple stimuli by the specializing of organs for and by each one, that the action becomes a regular and constant specialized function. The rods then as first differentiated are movable in an indifferent and imperfect way by all the various vibrations of the whole octave, or at any rate by the greater part of them. And the sensation as far as it goes would be that of dim and ineffectual colorless light like twilight. The first specialization from this state of things would be caused by the necessary fact that the retinal tissues are somewhat more mobile under the stimulus of some special ray of vibration, and this fact in turn may result from the circumstance that such special ray is the one most common in the surroundings in which the organ is environed. That most potent ray is the yellow, because it is experimentally demonstrated to be the most luminous; which is only another way of saying that it actually has the most powerful effect on organic tissues and the visual organ; and it is proved likewise to be the most powerful promoter of plant action.

Animals whose visual organs have reached this first differentiation would see sunlight as yellow instead of white. If now we suppose a

further modification on top of the yellow specialization, and still following the law of differentiation, we shall have the function of a yellow seeing cone gradually split into two sub-functions, the two together equal to yellow, the one above and the other below it, that is to say green and red. The general law referred to is, that when one part is specialized to the better performance of a function, the parts not involved in such specialization and from which the one part is separated, lose in their power to perform such function. That the eye is not exempt from the law is shown in the fact that the retina, which is an expansion of the optic nerve, is the only part sensitive to light while the rest of the nerve is totally blind.

As the rods and finally the cones are the sensitive parts of the retina we cannot logically exempt them from the operation of the law, and must hold that whenever one of them is altered in its functional nature, it is reduced to two parts whose functions are complementary of each other, one above and the other below the original; the elevation of one compensated by the degradation of the other. Thus we derive the green and red functions from the differentiation of some of the yellow, and in case of reversion and failure of the derived functions, we may retain in their place their original, the yellow. How many of the color functions have been differentiated directly from the rods by action of particular rays and how many have been specialized as subdivisions and sub-sub-divisions of the yellow, I shall not undertake to determine. But it appears probable that there is at least one other original center of specialization from the rods; viz., the blue.

At any rate if we suppose two or three such original centers all the other specializations could be derived from these by the repeated subdivision of function.

The number of sorts of cones we possess, according to this theory, is limited to the number of spectrum colors we can see. Our sensations of color are not however limited to these, because the sensations of these original colors can be so compounded and mingled in the receiving organs of the brain as to give the impression of an almost unlimited number of shades and varieties.

The number of cones in the yellow spot is said to be about 1,200,000, and the number outside of that is also vast.

It should be observed that, other things equal, the power of perceiving colors depends on the length of the cones; the taller they are the more acute the perception. So that where they are the most numerous they are also the largest. They are longer in the *yellow* spot than in the rest of the retina.

"The impression produced by the rays of light on the retina seems to be a kind of photographic action, for Professor Kühne has found that

the purple film termed the visual purple, which covers this delicate membrane, loses its color on exposure to light. He has indeed proved that it is possible to obtain upon this film a so-called optogram, or visible image fixed on the retina, of the object to which the eye may be directed. In the living eye the sensitive surface is quickly being renewed and consequently the eye constantly recovers its power." (Roscoe, Spectrum Analysis 32.)

CHAPTER XLVII.

COMPARATIVE ANATOMY OF THE EYE.

The construction of the mammal eye is in a general way essentially that described above even down to the rods of the retina. But in regard to the cones there are exceptions. And first, those nocturnal mammals, such as moles, bats, mice, &c., whose activities are chiefly confined to twilight, have no cones, and therefore presumably no sense of color. But they are provided with an immense number of rods, and must be sensitive to the faintest glimmerings of light. The great mass of the mammals, however, possess cones distributed among the rods as in man, and therefore must have a color sense. But with one exception no mammals beside man have the yellow spot. The exception is in the monkey and ape tribes. The possession of this peculiarity by the monkey, while separating him from the lower mammals, to an equal degree brings him nearer to man. In general, among the lower mammals, the proportion of cones to rods is about as one to three. The peculiar habits of animals have caused more or less variety of detail in the structure of the eye as of other parts. Thus, the cat and other animals have in the back part of the eye behind the retina, and either taking the place of the pigment coat or mingled with it, a carpet of glittering fibres called the tapetum. It is a powerful reflector and a very little light gives it a luminous appearance. It intensifies the stimulus of the light upon the rods and enables the animal to see with a small amount of light. The pupil of the eye, as before mentioned, is a mere opening in the curtain called the iris, and it is changed in size by the expansion and contraction of the iris. In certain animals, as the cat, fox, &c., the pupil is elliptical instead of round and contracts to a vertical line. This arrangement allows a greater variation in the size of the opening, closing tighter in the day and opening wider in the darkness, and is a manifest advantage to night prowlers in the same manner as the tapetum. But some have supposed that the vertical position of the opening, which gives a great vertical range of vision, indicates an animal living in the woods. Thus the pupil of the Genet, a timber animal, closes to a vertical line, while

that of its relative, the civet, living in an open country, remains round. (Cuvier.) The pupil of the sheep's eye is elliptical, but is elongated sidewise instead of vertically, whereby it is enabled to look far to right and left without raising its head, an advantage in grazing. The pupil of the eye acts automatically, contracting as the light increases. Heat on the other hand expands it. These effects can be produced on eyes for a considerable time after they are detached from the living body.

It has been shown that birds are related more directly to the reptiles than to the mammals. Nevertheless the essential features of the eye are still the same. Many birds whose habits require and cultivate long range of vision and acute discernment of color, have developed details that give them superiority over the mammals in these respects.

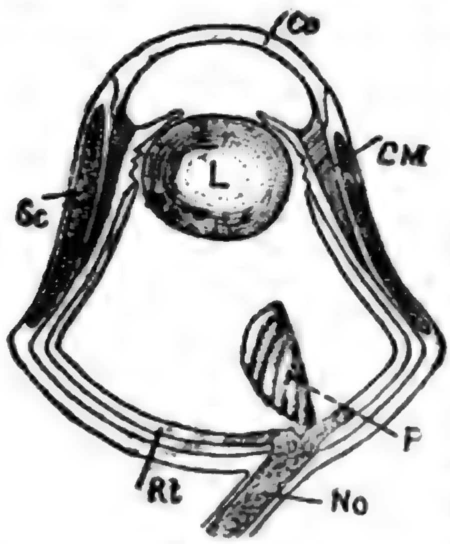


FIG. 177.

FIG. 177.—*Eye of Nocturnal Bird of Prey.*
Co.—Cornea.
L.—Lens.
Rt.—Retina.
P.—Pecten.
No.—Optic Nerve.
Sc.—Ossifications of the Sclerotic Coat.
C M.—Ciliary Muscle.
(*After Wiedersheim.*)

Lizzards, crocodiles, birds, and many fishes have a common property in a peculiar feature called the pecten or marsupium. Huxley describes this as a peculiar vascular membrane covered with pigment like the choroid, which projects from near the entrance of the optic nerve on the outer side of the globe of the eye (the side away from the nose) into the vitreous humor and usually becomes connected with the capsule of the lens.

The number of the cones in the eyes of most birds is greater than in mammals, the rule being that in birds the cones are three times as numerous as the rods. They generally have a yellow spot, and in the case of the Falcon and some others there are two yellow spots. This enables the Falcon to concentrate his vision on two objects with equal intensity at one time. Color can be distinguished further than form. Many birds, and reptiles too, have on the ends of their cones minute globules of oil. These vary in color and are light and dark green, yellow, orange, brown, red (carmine), light blue and white.[1] It is supposed these globules act like so many special lenses to concentrate the action of their respective colors upon the cones, thus intensifying their sensation. Each one represents to the bird one prime color, and it is able to discern not only this but all the shades that the mixtures of his prime colors will make, when mingled in various proportions and intensities.

The owl with its nocturnal proclivities manifestly must make small use of a color sense. He possesses but very few cones while he has an extraordinary number of rods. But his cones are provided with the

[1] Henry T. Finck.

oil globules and it is interesting to note that they are of a light yellow color. "Since yellow disappears in the twilight last of all colors it is probable that these globules exist for the purpose of collecting or intensifying the last traces of this color for the benefit of the owl on its nocturnal expeditions." (Finck.) The existence of these yellow globules in the owl after those of all other colors have disappeared through disuse, is strongly confirmatory of the theory advanced in the last chapter regarding color differentiation—that it begins with yellow One of the most remarkable and highly developed eyes as to color is that of the reptile Chameleon. Instead of having a spot like our yellow spot covered with color seeing cones, the entire retina of the Chameleon is covered with such cones, and as they are extremely slender they are far more numerous than ours in proportion to the space occupied. Add to this that they are much longer, and we have all the conditions that are required for excellence. This remarkable eye is intimately connected with that peculiar characteristic of the Chameleon by which its color undergoes rapid changes.

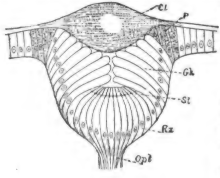


FIG. 178.

FIG. 178.—*Section of the eye or Ocellus of a Beetle Larva.*
Cl.—Corneal Lens.
Gk.—Hypodermis Cells; the equivalent of the *Vitreous humor.*
P.—Pigment in the peripheral cells of the latter
Rz.—Retinal cells.
St.—Cuticular rods of the latter.
Opt.—Optic Nerve.
(*Grenacher & Claus.*)

The eyes of insects are of two kinds. The first is the *Ocellus* or *Stemma*. It consists of a group of pigment cells under the skin, and connected inside with a nerve-filament. This simple form is found in the larva of the Bot-fly and others. The outside skin over this spot is transparent and convex, and calls to mind the cornea of mammal eyes. The ocellus exists in a higher degree of development in many insect tribes. The cornea becomes very convex and smooth, and under it is a spherical crystalline lens and beneath that, a body of vitreous humor. This advanced ocellus is the only sort of eye possessed by the spider and Myriapod tribes, with a small exception. And they are the only eyes of the larvæ of many of the six-footed insects. The other sort of eye is the compound eye. These consist of a great number of simple eyes set side and side; and by their crowding together their corneas or facets take the form of a hexagon generally, but sometimes a square. These facets are equivalent to lenses having convex faces, especially in the rear.

They number in the eye of the ant about 50, while in the eye of the butterfly as many as 3,650 have been counted. According to Agassiz some compound eyes have 25,000 facets. Behind these facets are crystalline rods enveloped in pigment connecting with nervous filaments through a pigment layer. These filaments connect inwardly with a ganglionary expansion of the optic nerve. A large number of six-footed insects when adult possess these compound eyes, two in number,

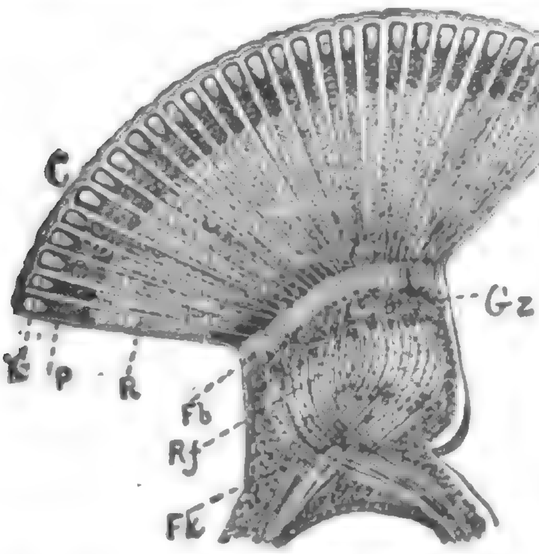


FIG. 179.

FIG. 179.—*Diagram of Compound faceted Eye of Libellula (Dragon Fly.)*
C.—Cornea.
K.—Crystalline Cone.
P.—Pigment.
R.—Nerve Rods.
Fb.—Layer of Fibres.
Gz.—Layer of Ganglion Cells.
Rf.—Retinal Fibres.
Fk.—Crossing of Fibres.
The faceted Eye occurs in Insects and Crustaceans; and enables the animal to take in a wide field of vision without moving.

and also three of the ocelli, the ocelli being situated between and a little in advance of the compound eyes. The number three, however, is inconclusive. The fact is, that under the influence of bilateralism there are originally four ocelli. The anterior single ocellus is formed by the fusion of two original ocelli as is seen in the development of the pupa of the bumble-bee (Bombus). Packard holds, that the articulate eyes are simply modified dermal sense cells. "In the embryos of all the insects yet examined the eyes are groups of specialized cells of the skin which grow out on the upper or tergal side of the same segment which bears the Antenæ."[1] They are not however confined to this segment in all the Articulates. In the king crab (Limulus) one pair of ocelli are found on the first segment, and the compound eyes are on the back of the third segment. Among the worms some, as the Polyophthalmus, have eyes on every segment, while some of the Planarians have them scattered irregularly over the body. In Spiders the number is usually eight and they are in a cluster on the front end of the back. In some of the Millipedes, the Pill-bugs for example, the eyes are collected in groups. These are in a sort of transition state between the single simple eye and the compound eye. In the Nereis, a marine worm, there are four eyes, of a very simple pattern; consisting of a black cup-shaped membrane or choroid which contains a small, white, opaque body flattened in front and rounded behind, and which is connected with the optic nerve. In front it is covered with a layer of epithelial cuticle. The eyes of the Craw-fish are compound like the eyes of insects but are set up on eye stalks. These are flexible tubes which can be turned in

[1] Packard On Insects 19.

all directions, even backward over the shoulder, and enable the animal to see behind without turning his body.

Among the animal forms below the articulates we find pigment spots with nerve attachments as the organs of vision.· Some of the Star fishes have such eyes, similar to those of the Nereis, on the points of their rays. They are also found in the Sea Urchins, at the margins of many Medusæ, and in some Polypi; and they have even been shown to exist in a large number of infusoria (Agassiz.)

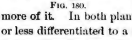


FIG. 180.

FIG. 180.—*Euglena Viridis, a Flagellated Infusorian.* S.—Red spot sensitive to light; an elementary eye.

Plants and many minute animals destitute of visible organs are observed to move with reference to light, generally trying to get more of it. In both plants and the little animals, certain parts are more or less differentiated to a degree of greater sensibility to the influence of light. The *Euglena Viridis* (figure 180) an infusorian which is about as much vegetable as animal, is sensitive to light in its anterior, flagellated end. And there it possesses a red pigment spot. Even the moving zoospores of certain Algæ have such a red spot, which Lubbock supposes to have reference to light. Most of the Mollusks have eyes or eye spots at

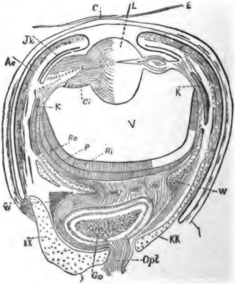


FIG. 181.—*Diagrammatic Section of the Eye of the* Sepia (*Cuttle Fish*).

C.—Cornea.
L.—Lens.
Jk.—Iris Cartilage.
E.—Epithelial Cover.
Ae.—External Argentine [Layer.
Ci.—Ciliary Body.
K.—Cartilage of Optic Bulb.
V.—Vitreous Humor.
Re.—Outer Layer of Rods.
Ri.—Inner Layer of Rods.
P.—Pigment Layer of Retina
W.—White Body.
K K.—Cephalic Cartilage.
Go.—Optic Ganglia.
*Opt.*Optic Nerve.

(*After Hensen.*)

some period of their lives, but as mentioned elsewhere, many of those that become fixed to a stationary object in the later and sedentary period of their lives, lose the eyes they possessed while in active youth. Many of the bivalves have simple eyes or pigment spots scattered along the edge of the mantle.

The cephalopods have two eyes. In the lower families these are quite rudimentary, sometimes consisting of mere pigment spots situated over the œsophagean ganglion, and at the base of the tentacles. But among the higher families, as the octopus and cuttle-fishes, the eyes attain a high degree of development. The eye of the Cuttle-fish (Sepia) is strikingly like that of the higher vertebrates, in all essential features, and differing only in details. The fig. 181 shows the lens resting on the vitreous body behind which is the retina in two layers, with a choroid or pigment layer between. The optic nerve does not pass through the coats of the retina and spread its fibres on its inner side as in the vertebrate

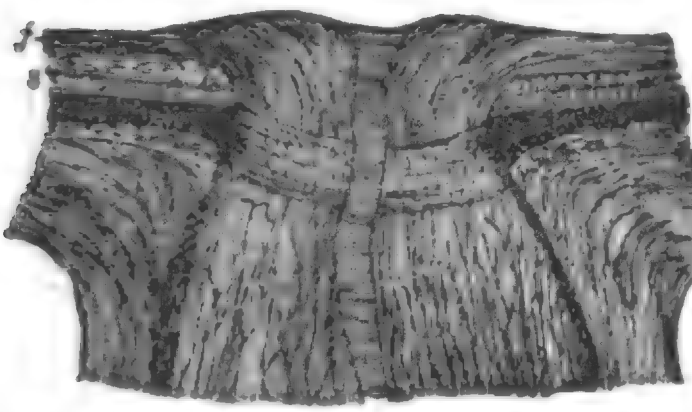


FIG. 182.—Showing Optic Nerve of Vertebrate Animals passing through the layers and spreading in front of them.
n.—Optic Nerve.
f.—Fibrous Layer.
s.—Sensory Layer—Rods and Cones.
(Compare with fig. 176.)

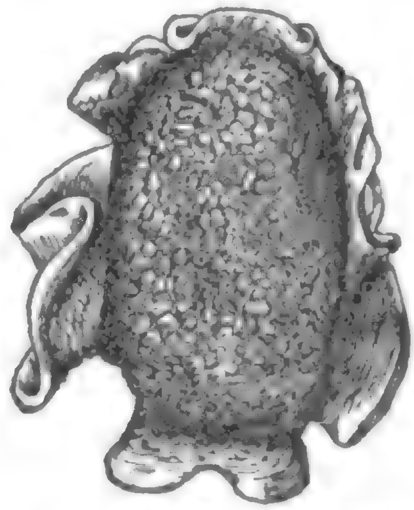


FIG. 183.—*Onchidium of Tonga.* A land mollusk living on sand beaches on the margins of seas or marshes; and having eyes on its back. (*After Semper.*)

eye, but spreads out on the back part or outside layer of the retina, so that the coat holding the sensitive crystalline rods is inside next the vitreous humor. There is therefore no blind spot as in man, the rods covering the whole of the retina. This would seem to be the direct original construction of the eye, while the vertebrate plan is an innovation, the optic nerve having pushed its way through the center of the layers and formed the retina wrong side out. The eyes of the gasteropod univalves (snails, &c.,), are at the tips of their tentacles or at their base. They resemble those of the cephalopod in their essential features, and differ from those of the vertebrates in the peculiar structure of the retina.

It is an exceedingly remarkable fact that both of these sorts of eyes are developed in a single animal. That animal is the *Onchidium*, a naked gasteropod mollusk. (Semper.) In its head are two eyes like those of the snail with the direct retina without the blind spot. But on

the back of this animal there is a large number—as many as ninety-eight have been counted in one individual—of regular vertebrate eyes with the inverted retina and consequent blind spot. The arrangement of the lens and other details are less complicated, but all the essential features of a useful eye are present, including rods, pigment layer, &c.

Fig. 184.

FIG. 184.—*Eye on the back of the Onchidium.*
n.—Optic Nerve passing through the other layers.
p.—Pigment. *l.*—Lens.
f.—Fibrous layer *s.*—Rods and Cones.
(*After Semper.*)

It is the only example of such an eye in an invertebrate animal. Semper has found them in twenty species of this family. They all differ in arrangement, but are normal in structure, which leads him to conclude that they originated in this family. These mollusks live along the sea-shore or in brackish marshes, hiding under stones or in clefts of rock. They are very slow and could hardly get out of the way of anything. They are pursued by two rapid and active genera of fishes called the Periophthalmus. As the Onchidium is out of its shelter scooping sand into its mouth, which is its way of getting at the particles of vegetable matter that forms its diet, this enemy sweeps down upon it and takes it in. Its only defense is from the supposed automatic action of these eyes. There are throughout the skin of the back of the onchidium a great many small glands which secrete a sort of dense fluid and which, when it is suddenly alarmed by the shadow of its enemy, it is supposed to suddenly contract and throw the fluid upward in small globules through the minute pores which form the outlets of the glands, a performance which may alarm or injure the pursuer in some way. At any rate there seems to be a mutual relationship between these eyes and that fish; for the mollusk and the fish are found together over a great extent of the eastern coasts of Africa, Asia, and Australia, and the Malayan Archipelago, the mollusk having the dorsal eyes.

There are many species of the Onchidium without the dorsal eyes or the accompanying glands, living in places not frequented by these Periophthalmi. These are found on the Atlantic coast of France, England and North America, the Gallapagos Islands, New Zealand, &c. This active fish is therefore a selective agency in destroying those families of Onchidiums which are not defended by the dorsal eyes, while they can hold their own where he is not. The sudden contraction of the integument by which disagreeable matters are discharged, and which serves for a more or less effectual defense, is characteristic of several families of mollusks, as the Loligo or Squid, the Sea-squirts, Ascidians, &c.

This contraction is in sympathy with either the organs of sight or touch. But the fish has a stimulating effect on the habits of the Onchidium tending to develop an alertness and activity, such as in some animals shows itself in general muscular movement of limbs, but in this (and others) is shown in molecular changes of the body and the stimulation and growth of sense. The back of the Onchidium is often covered with eyes in various stages of development, and they all, even when no eyes are developed, possess tubercles of various sizes, which are rounded and smooth. These tubercles or papillæ differ greatly in size, and increase in number with the age of the individual. The smaller ones show nothing under the outer cuticle except a simple cellular layer, the epithelium, like all the univalve mollusks, but in the center of the larger ones a cellular mass is found growing inward and downward from the epidermis. From some masses of this kind the glands for the secretion of the fluid are formed, and others become granular and crystalline, refractive and more sensative to light. In still larger papillæ a layer of pigment closes around the differentiated cells, a few of which are consolidated into a crystalline lens, and a nerve fibre can be detected communicating with the interior. Thus the sensitive papillæ, which in most animals remain organs of touch, are in this one, converted to a considerable extent into organs of sight. (See fig. 173.) They thus occur in all stages of development in some individuals, and are in different degrees of perfection in different species; being in some quite rudimentary, in others remarkable for their perfection and utility. "In the Chitonidæ, a family of gasteropod mollusks in which dorsal eyes have recently been

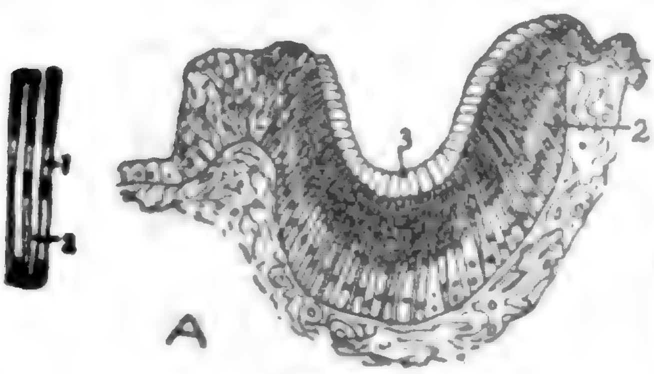


FIG. 185.

FIG. 185.—*Perpendicular section through the eye-pit of a Limpet—Patella,* (*After Carriere.*)

1.—Epithelial Cells.
2. Retina Cells.
3.—Vitreous Body.

This eye consists merely of differentiated epithelial tissue.

Limpet is a Gasteropod univalve mollusk. Its eye-pits are placed at the root of the tentacles and just outside of them.

discovered by Mosely, they are even more numerous" than in the Onchidium. "Chiton itself indeed has none, but in Schizochiton there are 300, and in Corephium more than ten thousand! As in Onchidium they probably arose as modifications of the organs of touch and are supplied by the same nerves. They possess (1) a cornea, (2) a perfectly transparent and strongly biconvex lens, and (3) the retina which presents a layer of short but well defined rods. It is interesting that they point towards the light and not, as in Onchidium, away from it."[1]

[1] Lubbock Senses of Animals, 144.

The progressive development of the eye from the sensory skin is well seen in the Gasteropod Mollusks. Thus the eye of the Limpet, (fig, 185,) shows a mere indentation or partial *invagination* of the skin and apparently a modification of the outer layer of the epidermal cells into a transparent, glassy sort of body, the forerunner of the vitreous humor and crystalline lens; while the under layer becomes the sensitive retina.

Fig. 186.—*Eye of Trochus Magus, a Gasteropod Mollusk.*
It is a little more developed than the eye of the Limpet.
G L.—The Vitreous Body.
N.—Nerve. *After Hilger.*

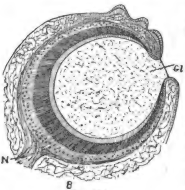


Fig. 186.

Fig. 187.—*Eye of Murex brandarts, a Gasteropod Mollusk.*
(*After Hilger.*)
This eye is an improved modification of that of the Trochus Magus; a part of the *vitreous body* having become set off into a *lens.*
L.—Lens.
Gl.—Vitreous Body.
N.—Nerve.

In the eye of the Trochus magus, another Gasteropod, (fig. 186,) the development has gone further. The invagination is about completed and the "vitreous body" almost enclosed. The shape of the vitreous body must give it the force of an imperfect lens, in concentrating the light. In the eye of the Murex, another Gasteropod, we have a still further advance. Here the vitreous body is not only fully enclosed, and covered in front by a transparent epidermal layer grown over from the sides, but a spherical lens has become set off from the rest of the vitreous humor.

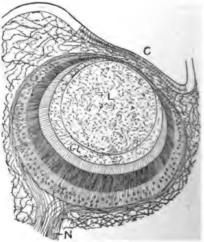


Fig. 187.

In these "invertebrate eyes," the fibres of the optic nerve, which receive the impressions of light, lie behind the sensitive layer of the retina instead of in front of it, as in the human eye; and so there is no hole in the retina made for the passage of the nerve, and consequently no

blind spot. But now we have a curious compromise between the sorts of eyes, in another mollusk, a bivalve this time, like a scallop belonging to the oyster family. It is called the Pecten. In this ey

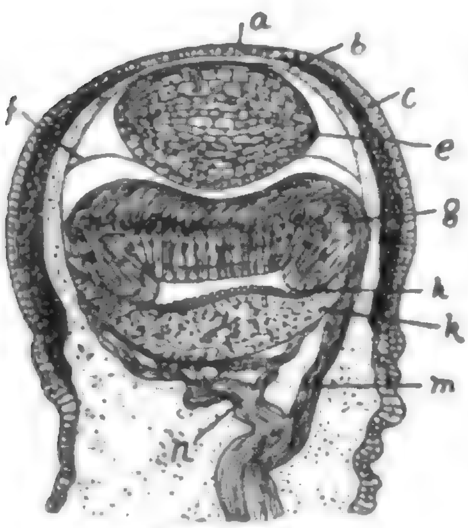


FIG. 188.

FIG. 188.—*Diagram of the Eye of Pecten, a bivalve of the Oyster Family.* (*After Hickson.*)
a.—Cornea.
b.—Transparent Basement Membrane supporting the epithelial cells of the Cornea.
c.—The Pigmented Epthelium.
e.—Lens. *f.*—Ligament supporting it.
g.—Retina. *h.*—The Tapetum.
k.—Pigment. *m.*—The Retinal Nerve.
n.—Complementary Nerve.
The nerve goes *around* to the *front* of the retina instead of the *back* as in most invertebrate eyes, or instead of *piercing* the layers as in the vertebrate eye.

fig. 188, the nerve passes around the edge of the retina and spreads its fibres in front; so the light passes through them to reach the retina as it does in the vertebrates.

The vertebrate eye in the lower orders is almost as rudimentary as in lower invertebrates. In the Amphioxus and Hag-fish or Myxine it consists of a rudimentary lens imbedded in the pigment which encloses the termination of the optic nerve. (Huxley.) The eye of the Myxine is overgrown with muscles and skin, which seems to imply that it has seen better days and is falling into decay.

There are some examples among the vertebrates of extraordinary eyes in unusual places, as well as among the mollusks. Thus there are no less than eight genera of the Salmon family in which such organs in greater or less degree of perfection are found. The genera Chauliodus, Astronesthes and Stomias possess eyes distributed on the belly and tail. This is agreed to by both Leukart and Semper. Two genera, Sternoptyx

FIG. 189.—*Section through the Eye of Esox Lucius* (*Pike Fish*).
Co.—Cornea.
L.—Lens.
Pf.—Falciform process—a fold of the Choroid Coat.
C. H.—Campanula Halleri—attached to the Lens.
Sc.—Ossifications of the Sclerotic Coat.
No.—Optic Nerve. (*After Claus.*)

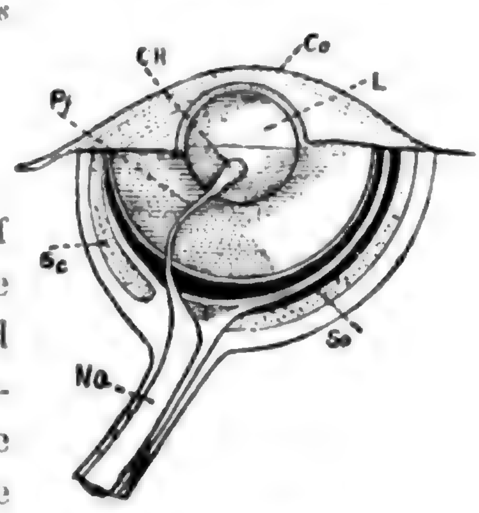


FIG. 189.

and Argyropelicus, have organs in a stage of development between pigment spots and true eyes, while the Scopelus, Gonostoma and Maurolicus have pigment spots in the corresponding parts of the body, which are therefore supposed to be the incipient stage of the same organs.

In the fishes the regular paired eyes usually have a rather flat cornea. This is compensated by the superior concentrating power of the lens, which is almost spherical. They also have a folding of the choroid or pigment coat called the falciform process, which appears to correspond with the *pecten* in the eye of birds. (See fig. 177.) There is also a

peculiarity in the optic nerve of fishes. This nerve instead of being cylindrical is composed of a number of folds side by side. It is shown spread out in fig. 190. This will be mentioned again.

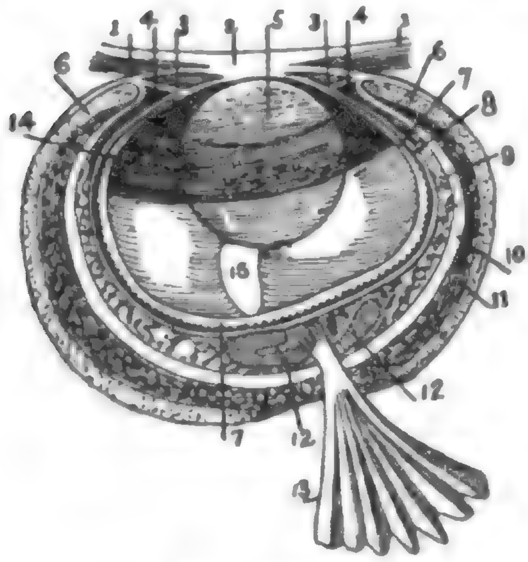


FIG. 190.—*Eye of Sword Fish.* (*Owen.*)
1.—Outside Skin Modified over the Eye into
2.—The Cornea.
3.—Pupil.
4.—Iris and ciliary ligament.
5.—Lens.
6.—Ossified Capsules of Sclerotic.
7.—Retina.
8.—Uvea or Pigment Membrane.
9.—Vascular Membrane.
10.—Argentine Membrane.
8. 9. 10.—Together are called the Choroid Tunic.
11.—Adipose and Cellular filling.
12.—Choroid Gland.
13.—Optic Nerve spread out.
14.—Ciliary Process—border of the Uvea.
15.—Falciform process of the Vascular Membrane of the Choroid, pushed up and attached to the Lens.

FIG. 190.

A good deal has been said to show the loss of function by disuse. The eye and other features of the organism that are built up by habits originating in the energy of light, are likewise lost or reduced by disuse and darkness. Some examples have been given. The Amblyopsis Speleus is a fish living in Mammoth Cave. It is entirely blind and is destitute of even the orbital cavity. There is also a craw-fish in the same cave, viz., the *Astacus pellucidus*, whose eyes are likewise reduced to rudiments, the pedicels or tubes remaining, while the facets have disappeared.

The Proteus of the subterranean lakes of Austria is a blind batrachian whose connections above ground possess organs of sight. The eye of the Proteus is reduced to the retina and pigment layer, the crystalline lens and vitreous humor having disappeared. It is deeply seated in the head and entirely covered with skin. The eye of the Mole is also covered with skin. It is very small. It has a simple retina and an undeveloped lens, but one or both optic nerves are always aborted in the adults. The embryo, however, *always have both optic nerves* well developed. This proves the eye of the adult mole to be a rudiment in process of atrophy, like the human inter-maxillary bone, or teeth in the embryo whale, and it proves that the ancestors of the Mole were possessed of good eyes, and were therefore of different habits. The Mole inherits good eyes from his ancestors, but his environment is gradually undoing what the enviroment of his ancestors gradually did.

A peculiar family of crabs, the Pinothendæ, in their second stage of existence inhabit the interior of some mollusk. In their first or larval state they are lively creatures with tail, limbs and well developed eyes, and swim in the water. In order to develop into their second, mature stage they manage to gain ingress to some of the branchial cavities of

the mollusk by means of the ingoing current of water, and their continued growth to maturity there includes the entire atrophy of their eyes so that not even a pigment spot is left. There, however, they reproduce their larvæ with complete eyes, and turn them off into the water to look out for themselves, which they do by repeating the ancestral example. (Semper). This case is like that of the mole; and if either animal were forced to finish their whole lives in light, after some generations they would cease to lose their eyes.

CHAPTER XLVIII.

HEARING, AND THE EAR.

The sense of hearing depends upon the fact, that vibrations of a certain sort are able when they strike the ear, to set up in it a motion which it is able to communicate to the auditory nerve in the shape of a nerve current, which flowing to the brain excites in certain brain cells the motion we call hearing. Whatever the nature of the motion, after it agitates the ear, the nerve and the cell, it is certain that before it reaches the ear, it includes vibrations of some ponderable substance, commonly the air. As stated in chapter 39, the pitch of these vibrations runs

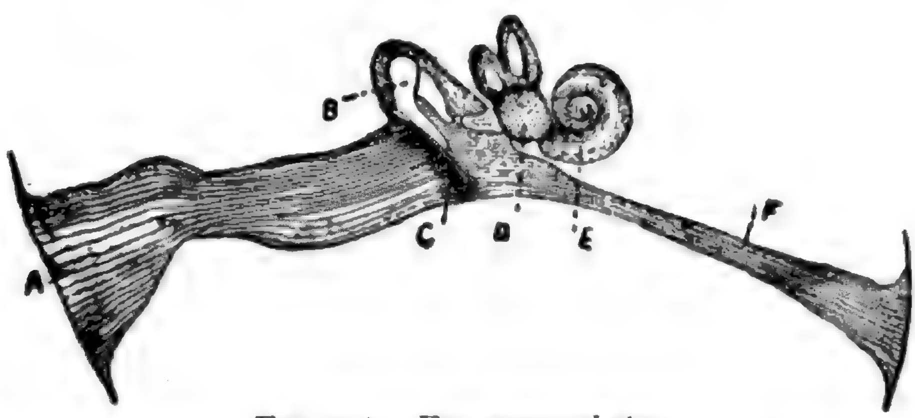


FIG. 191.—*Ear, natural size.*

A.—Outside ear or conch (or flap).
B.—Ear bones.
C.—Tympanum—drum-head.
D.—Utriculus with Canals.
E.—Cochlea.
F.—Eustachian tube opening into pharynx. (*After Helmholtz.*)

from about 33 up to 30,000 or 40,000 per second. The essential part of the ear, in most animals, is a sac of water which receives the vibrations, and connected with which is the auditory nerve, which conveys the stimulus to the brain. In very few is the organ confined to this simplicity of construction. Various appendages are found in the ears of the more highly developed animals, which serve to intensify the sensation, to make it more acute, and finally to make it discriminating, that is to have a different sensation for different qualities and pitch of sound. A description of the human ear will serve as a good basis for study and standard of comparison for others.

In the first place the external ear, or ear flap, is in man not essential, or even helpful, to the sense of hearing, but is a mere rudiment. Nor is the ear flap possessed by birds. The ear flaps with the tube called the auditory canal, or external meatus, leading in from it, constitute the external ear. At the inner end of the auditory canal is the tympanic membrane which is stretched across the opening, and forms its inner terminus. Inside of the tympanic membrane is the chamber, which with its contents constitutes the middle ear—the tympanum, or drum. The tympanic membrane is one head of this drum, the one that receives the original vibrations. On the opposite side of the drum from this head, are two small membranes, which separate the drum from the internal ear or third portion. This internal ear is the essential part, and

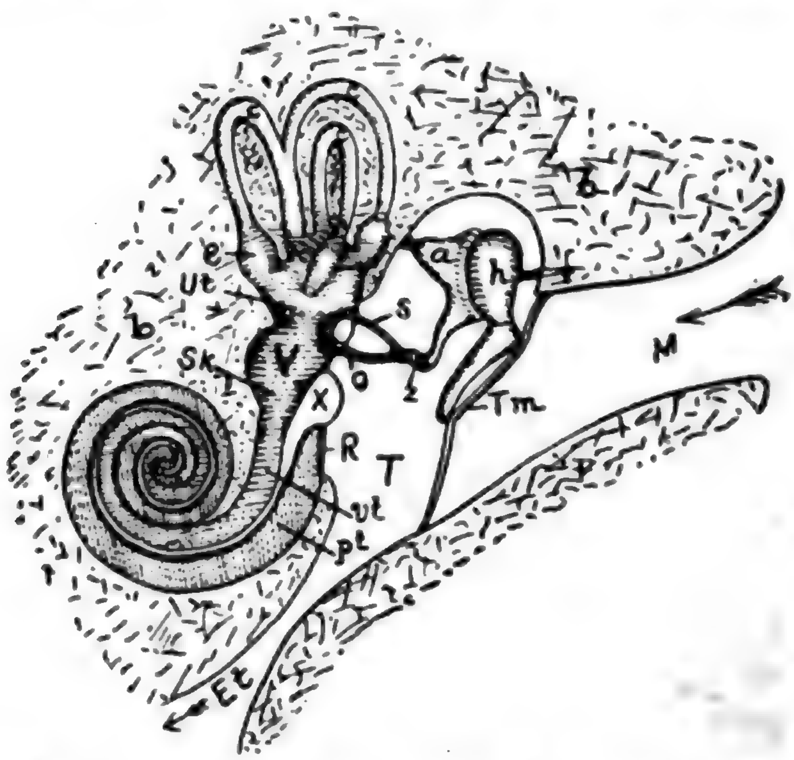


Fig. 192.—*Partly Diagrammatic Scheme of the Ear.*

M.—Meatus or external opening; arrow pointing in.
Tm.—Drum-head or tympanic membrane.
T.—Drum or tympanic cavity or middle ear.
Et.—Eustachian tube; arrow pointing to the pharynx.
h.—Hammer; *a.*—Anvil; *z.*—Orbicular bone.
s.—Stirrup resting upon o.
o.—Fenestra Ovalis—oval window.
R.—Fenestra Rotunda—round window (in profile).
c.—Three Semicircular Canals; *e.*—Ampullæ.
Ut.—The Utricle.
Sk.—The Sacculus.
V.—Vestibule.
vt.—Scala Vestibuli, }
pt.— " Tympani, } Cochlea.
x.— " Media, }
b.—Bone.

(*After Landois and Stirling.*)

like that of the simplest animals, consists primarily and essentially of a watery fluid suspended in and around membranes, upon which are terminations of the auditory nerve. The watery fluid, or lymph, as it is called, is contained in three subdivisions of the internal ear. The simple sac of the invertebrate ear is in the human ear, represented by two sacs of very peculiar shape. One of these is called the scala media, the other the membraneous labyrinth. The two are surrounded by

and suspended in a fluid called the perilymph, while the fluid contained in them is called endolymph. Each of the bags is held in a peculiar shaped bony cavity, and corresponds to its cavity in shape, but does not fill it, the spare space being occupied by the perilymph. The membranous labyrinth is above and toward the rear from the scala media, and consists of three hoop-like cylinders called the semicircular canals, which communicate with a common chamber below by five openings, each end of each canal opening into the chamber, except in one case, in which two come together before entering the common chamber. This chamber is called the vestibular sac. At their lower ends the canals are swelled or expanded, such expansions being called ampullæ or "bottles," fig. 192, *e*. The scala media is contained in a bony cavity called the cochlea. This is situated a little below and forward of the semicircular canals. In shape the cochlea is like a snail shell, and in the human ear it is coiled two and a half times around the central, bony stem, which is called the modiolus. The cavity which thus runs in a spiral direction up the cochlea, is divided by two longitudinal partitions, so as to make three long spiral tubes winding from bottom to top. The lower and under one is the scala tympani, the upper one the scala vestibuli, and between these two is the scala media. This, as before stated, is a membranous sac containing the endolymph. Around its upper end the other two scalæ connect with each other. They are filled with perilymph. The two membranes spoken of above as separating the ear drum or tympanum from the cavity of the inner ear, are named respectively the Fenestra Ovalis and the Fenestra Rotunda (the oval window and the round window). The former of these is opposite the vestibular sac before mentioned, the space between it and the sac being named the vestibule. The latter is lower and further forward, and forms one end of the scala tympani. The scala vestibuli at its lower end merges into the vestibule by a narrow opening called "canalis reuniens." (Fig. 209, *cr.*)

The vibrations by which the fluids of the inner ear are agitated are communicated to it by mechanical vibrations upon the membrane of the fenestra ovalis. When that membrane is compressed or pushed in, the jar is communicated to the perilymph in the vestibule, and from thence to that which surrounds the membranous labyrinth in the semicircular canals, and also from the vestibule up the scala vestibuli around the head of the scala media, down the scala tympani to the fenestra rotunda, which is pushed out towards the tympanum, thus acting as a safety valve. Of course, whenever the perilymph is shaken up it communicates the agitation to the endolymph which is contained in the two sacs above described. From this it is communicated to the ends of the auditory nerve, and by it conveyed to the balancing organ in the brain. To go back to the

tympanic membrane which receives the first agitation from the air or outside world; it is stretched across the inner end of the auditory canal in a diagonal or oblique direction. The agitation of this membrane is conveyed across the inner part of the drum to the fenestra ovalis by means of a chain of small bones, four in number, and peculiarly arranged.

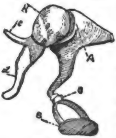


FIG. 193.

FIG. 193.—*Bones of the Ear.*
A.—Incus or anvil.
H.—Hammer or Malleus.
d.—Hammer Handle attached to Tympanum.
C.—Long process.
O.—Os Orbiculare.
S.—Stapes, attached to Fenestra Ovalis.

The one next the tympanic membrane and permanently attached to it is the malleus or hammer. When agitated it jars upon the one next it which is called the incus or anvil. Next to the incus and separating it from the last bone which is called the stapes or stirrup, is the very small, round bone called the os-orbiculare. It is frequently fused with the anvil bone. The head or top part of the stirrup is connected with the orbiculare while its foot is planted directly flat on the fenestra ovalis. The tympanum is an organ of noise, but not of music. If it had a single fundamental note we could get no knowledge of any noise except that of one particular pitch. But the contact of the hammer handle across its disc gives it an uneven and complicated tension, so that it is jarred by all sounds within certain limits.

FIG. 194.—*Human Labyrinth and Ear bones magnified.*
a.—Stapes (stirrup) covering the fenestra ovalis.
b.—Fenestra rotunda (round window).
c.—The horizontal canal.
d. e.—The perpendicular canals.
f.—Cochlea (snail).
g.—Incus (anvil).
h.—The long process of hammer.
i.—Head of Malleus (hammer).
j.—Mannbrium (handle).
k.—Os-orbiculare (the smallest bone in the body).
l.—Junction of canals.
m m m.—Ampullæ.

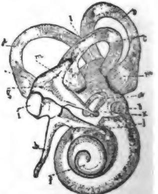


FIG. 194.

The cavity of the drum is thus enclosed by the tympanic membrane on the outside and bounded by the membranes of the two fenestras, or windows leading into the two internal sacs, on the opposite or inner side. It has one opening, however. A cana called the Eustachian tube leads from the front part of the drum, from point between the tympanic membrane and the fenestra rotunda, to th pharynx (fig. 191, *F* and 192, *Et*). This tube allows air to pass from the throat to the drum of the ear, and in cases of diseases of the tym

panic membrane, sounds have been communicated to the fenestra ovalis by way of the throat and this Eustachian tube. The inside of the two sacs is lined with epithelium, or the sensitive continuation of the outside epidermis or skin, which, as shown elsewhere, is, during the process of embryonic development, pushed in, or invaginated from the outside, and afterwards pinched off or detached from the epidermis as sacs. In the inside of the ampullæ, there is a fold or ridge of the epithelium, which is called the *Crista Acustica*, or acoustic crest. The fibres of the

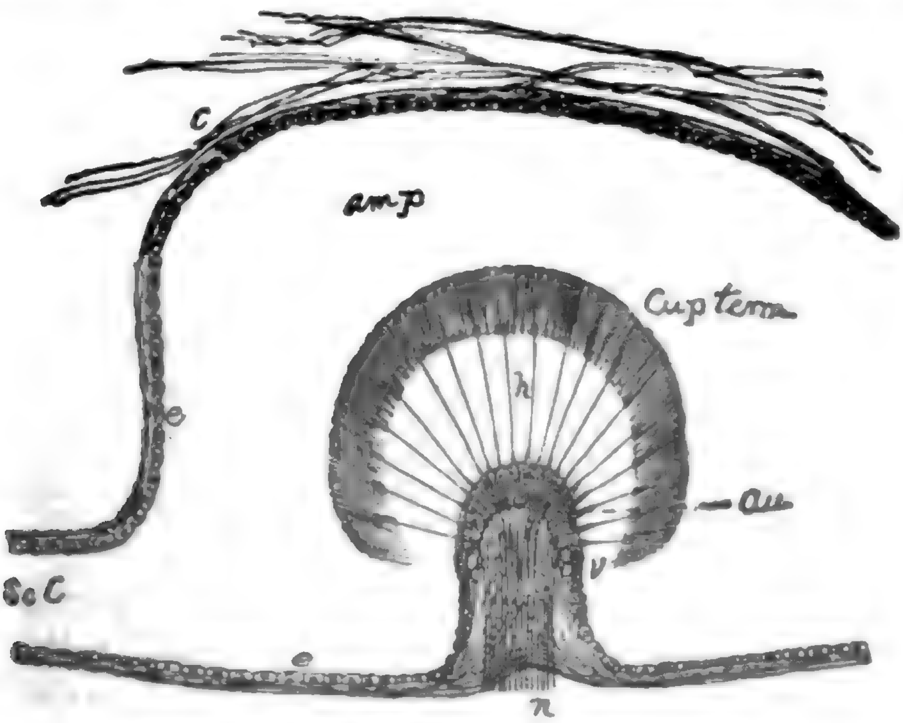


FIG. 195.—*Longitudinal Section of a Human Ampulla through the Crista Acustica.* Semi-diagrammatic.
amp.—Cavity of the Ampulla filled with Endolymph.
v.—*Crista Acustica*—the letter marks the lower limit of the auditory epithelium.
au.—Columnar cells of the auditory skin or epithelium.
h.—Auditory hairs projecting into the Cupula.
cup term.—The Cupula Terminalis.
n.—Nerve fibres entering the base of the Crista and passing into the columnar or auditory cells.
The Cupula Terminalis in which the hairs terminate is a soft material of semi-fibrillar structure. Thus embedded, the ends of the hairs do not vibrate singly, but the agitation of the endolymph must vibrate all. (*From Quain After E. A. Schafer.*)

auditory nerve penetrate this ridge from the outside, and communicate through the cells which cover the ridge with a great number of stiff bristles which stand on the ridge. These bristles extend outward into the endolymph which fills the ampullæ as well as the connecting canals, and whenever the endolymph is vibrated the motion is communicated to the hairs and by them transferred to the cells. From the cells it passes, as a nerve current, up the fibres of the auditory nerve to the brain. (See fig. 195.) There are some of these auditory hairs also in the body of the membranous sac with which the canals connect. In this part of the sac there are also a number of calcareous crystals called otoliths—ear-stones. These are suspended by nerve filaments and intensify the agitation of the nerves when the fluid is vibrated. The auditory nerve divides into two principal branches, one of which is called the vesti-

bular, and distributes its fibres to the vestibule and the ampullæ, while the other runs up the center of the stem of the cochlea and is called the cochlear nerve. This last sends fibres to receive the agitation of a very remarkable set of organs found in the sac described above as the scala media.

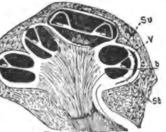


FIG. 196.

FIG. 196.—*Section of Cochlea of foetus of Calf*, from top to bottom, cutting across the Scala Tympani, Scala Vestibuli and Scala Media. Modiolus not yet ossified. Organs of Corti begun.
st.—Scala Tympani.
b.—Basilar membrane holding Organs of Corti.
sv.—Scala Vestibuli.
v.—Membrane separating the S. Media from the S. Vestibuli.
Scala Media lies between the membranes *b* and *v*. (*After Kölliker.*)

This, as before stated, is coiled around the stem of the Cochlea, having the scala vestibuli above and the scala tympani below it; from each of which it is separated by a membrane. The membrane which forms its bottom is called the basilar membrane. The inner edge of the basilar membrane is supported by a bony process which constitutes a portion of the bony stem or modiolus, the hollow conical pillar around which the three scalas gyrate like a three story stairway. The width of the basilar membrane increases regularly from the bottom to the top. The membrane is traversed from side to side by cross fibres, in fact it is composed of cross fibres laid side by side in vast numbers. The remarkable organs alluded to are called the organs of Corti. They consist of a series of arches, each arch composed of two fibres arranged to partly span across the basilar membrane. The arches stand on, and are parallel with the cross fibres of the membrane, probably one arch on each fibre. The shape of the arches is shown in fig. 198. The left hand fibre, the inner one, stands on the inner edge of the membrane next to the modiolus, the outer one rests not far from the middle of the membrane. The two fibres are joined at the top to form the arch, and then turned outward into a short prolongation, as shown in the figure. The span of these arches regularly increases from the bottom to the top of the scala. so that the upper arches have a greater span, though no greater rise, than the lower ones. The number of the arches is about 4,000. The space upon the basilar membrane not occupied by the arches is

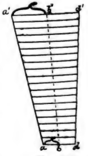


FIG. 197.

FIG. 197.—*Diagram of the Basilar Membrane; the floor of th Organs of Corti.*
a b d.—Lower end of the stairs in which the arches of Corti are of shorter span.
a' b' d'—Upper end.
(The membrane of an infant, measured by Hensen, was one-fiftieth of an inch wide at the summit and one three-hundredth at the lower end.)

covered by epithelial cells which connect by fibres with the prolongation of the arch fibres at the top of the arches. A branch of the auditory nerve runs up the cavity in the center of the modiolus. The central part of

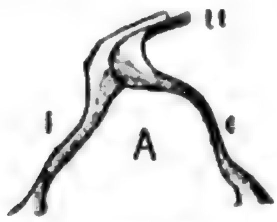


FIG. 198. A—*Single pair of the Organs of Corti.*
i.—Inner fibre; next the modiolus.
e.—Outer fibre.
t t.—Connection and prolongation of the fibres at the top.

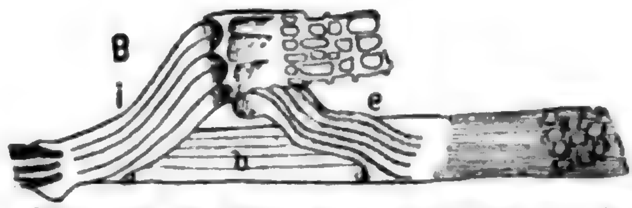


FIG. 199. B—*Five Organs of Corti* as they stand together on the Basilar membrane.
i and *e.*—Inner and outer fibres.
b.—Basilar membrane.
(*Bernstein,*)

the modiolus is pierced, laterly, by numerous foramina or minute holes, through which fibers from the nerve penetrate and reach the basilar membrane and the epithelial cells thereon and the arches.

It is generally admitted that the sensations of noises without regard to tone are produced through the action of the endolymph in the labyrinth in connection with the movement of the otoliths and the filaments on the crista acustica. These delicate organs respond faithfully to the impulses reaching them from without, by peculiar and varied movements in answer to the peculiar nature of the irritating noise, whether smooth and continuous, interrupted and jerky, loud or soft. But it is believed by investigators that it is the office of the organs of the basilar membrane, including the arches of Corti, to receive the impulses which give the sensation of pitch and tone.

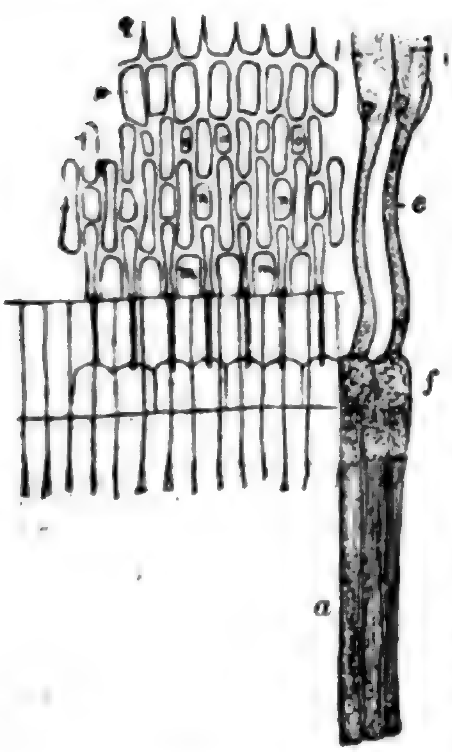


FIG. 200.

FIG. 200.—*Top view of the Scale* showing two arches of Corti on the right. On the left they are removed and the arrangement of nerves and cells beneath them is shown.
a.—Inner Fibres of Corti next to the modiolus.
e.—Outer Fibres of Corti.
f.—Their junction at the top.
i. Their attachment to basilar membrane.
m n o—and all similar parts of the fig. represent spaces, and the alternating parts are nervous connecting elements with nerve fibres extending inwards towards the modiolus.
p q.—Square terminal formations.

The arches of corti are like so many resonators, (see chap. 39,) and when a sound is carried to them through the endolymph of the scala media, the particular arch susceptible to the agitation accompanying that sound will be stimulated and transfer its stimulation to its fibre of the auditory nerve. If the sound is a compound one, as nearly all musical sounds are, each simple sound and harmonic composing it will find and agitate the arch corresponding to it, and so when all the stimuli

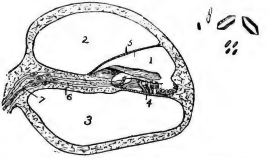


FIG. 201.—*Transverse Section of a turn of the Cochlea.*

1.—Passage of the Scala Media.
2.— " " " Vestibuli.
3.— " " " Tympani.
4.—Basilar Membrane supporting Organs of Corti.
5.—Reissners membrane.
6.—Bone of the Modiolus.
7.—Fibres of the Cochlear nerve to supply the Organs of Corti.

Figures on the right—Calcareous Otolith Crystals.

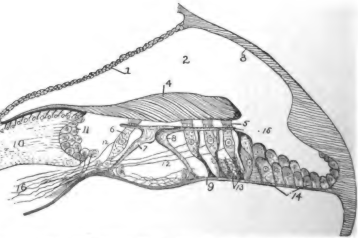


FIG. 202.—*Scheme of the Scala Media and Organs of Corti.* (*Landois & Stirling.*)

1.—Membrane separating the Scala Media from the Scala Vestibuli (Membrane of Reissner).
2.—Cavity of Scala Media.
3.—Outer wall of the Cochlea.
4.—Membrane of Corti covering the rods and hairs.
5.—Outer hair cells, in 3 or 4 rows numbering 12,000 in all.
6.—Inner hair-cells, *one* row about 4,000.
7.—Inner rod of Corti.
8.—Outer rod of Corti.
9.—Basilar membrane.
10.—Bony Center of Cochlea or Modiolus.
11.—Cells in the sulcus or groove of Modiolus.
12.—Nerve fibres passing to the hair cells.
13.—Supporting cells.
14.—Cells filling space near outer wall.
15,—Reticular membrane.
16.—Cochlear Nerve.

reach the brain the compound effect is reproduced there. As there are about 4,000 of these arches, and seven octaves include about all the sounds we can distinguish, it follows that we ought to be able to cultivate a perception of about 570 intervals in each octave, or over 47 for

each semitone. It is claimed that some of the best musicians can distinguish or even produce as great a number as that or even greater, in the three octaves possible to the human voice.

While there can be little or no doubt about the function of the scala media as a whole, being the reception and transfer of tones of musical pitch, such function cannot reside exclusively with the fibres of corti, since perception of pitch is possessed by animals destitute of those organs. Probably the function first arose from the circumstance that the sac of the scala media being of different widths at the opposite ends, it would naturally be of a different fundamental at different parts; so that tones would be selected, one passing through one part, another, another part. These parts subsequently became the track of the cross fibres of the basilar membrane, and at last of the arches of corti.

The jarring of the endolymph of the canals and of the scala media constitutes the last of the mechanical movements of ponderable substances, which up to this point appear to be the essential concomitants of sound stimulations. From this point forward the movement is the nervous electrical current up the auditory nerve and the polar disturbance of certain brain cells, constituting the sense of hearing.

Since polar disturbances and nerve currents are accidents of Ether, and since Ether is everywhere, it is reasonably probable that the nerve current is a continuation of a previous ethereal movement begun at the body emitting the sound in the first place, and accompanying the vibrations of air to the ear drum, and of the bones to the fenestra ovalis and the endolymph. The form of the motion of the Ether differs with its environment. In the embrace of pulsating air it is a pulsation, in a nerve it is a current.

The common quality of the organic matter of which all the classes of animated nature are composed, is to some extent proved by the fact that all animal ears have been differentiated by the same octaves. It has been suggested by an ingenious writer[1] that the hearing of insects is adapted to the octaves above ours, and their sensation of continuous sound begins at say 3,000 vibrations per second, while ours ends about there and begins at 32. He reasons from the *size* of the hearing organs of insects. But we are to consider that it is the sounds of the environment, the sounds to which the animal organism is most exposed, that develop the sense of hearing. These sounds are such as he makes himself; the calls and signals from one to another, the noises by which the presence of an enemy or the prey is betrayed. A man who can hardly hear the voices of his fellows is partially deaf and must use an ear trumpet to help out his defective hearing apparatus. Like him would be the humble-bee that could not hear a hum, the cricket to which a

[1] Mattieu Williams "Current Discussions in Science."

crick is inaudible, the gnat that cannot hear the singing wings of his brother. Insects are not exempt from the vicissitudes to which the rest of animated nature is exposed, and there is the same necessity in their case, as much as the rest, to know the running water by its murmur, the moving wind by its sighing or its roaring, the storm by its thunder and the patter of the rain. That insects may possess organs more easily impressed than ours is not improbable. They may hear sounds so faint and soft as to be quite unable to agitate our heavier apparatus, but their *pitch* must include ours substantially.

The hum of a bee produced by the vibration of the wings, while gathering honey is pitched on A′, the rate of which is 440 per second. When tired, however, he comes down to E′, 330 per second, but when excited or angry the pitch becomes different.

Beside the sound made by its wings, the fly has a voice produced by the stigmata of the thorax. This sound can be heard when the wings and other parts of the body are held still, or even cut away. (Packard Study of Insects.) Many insects seem to be endowed with hearing organs in more than one part of the body. In a great many there are such organs in the antennæ. In the grasshopper tribes and in ants and some other insects the hearing organs are in the front legs. These hearing organs include a series of vesicles each connected with a nerve fibril, and each containing an auditory rod. These auditory rods are peculiar to insects.

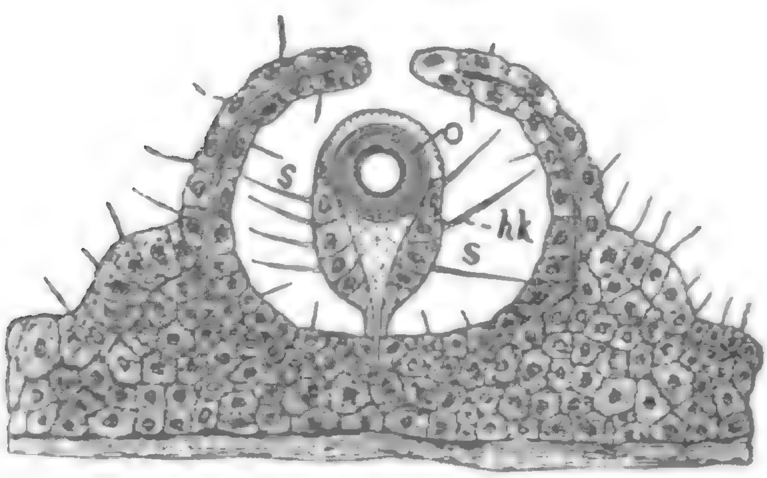


FIG. 204.—*Ear of Rhopalonema, a Jelly-fish.*
(Compare with ear of Ontorchis, fig. 203.)
This ear is developed from a Tentacle.
hk.—Modified Tentacle.
o.—Auditory Organ.
s.—Cup-shaped space nearly enclosed.
(*After Hertwig.*)

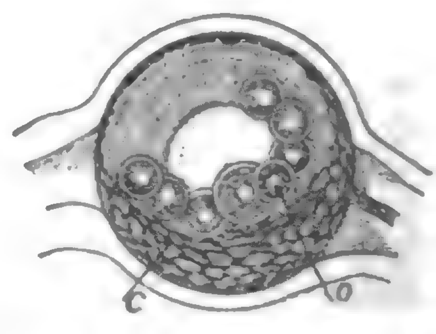


FIG. 203.—*Ear of Ontorchis, a Medusa or Jelly-fish.*
c.—Cells.
o.—Otoliths (ear-stones).
The body of the organ is an open pit situated on the margin of the umbrella. The cells and otoliths are connected by nerve fibres which are continued inward to the inner nerve ring. The number of these organs is 60 to 80; but in some species there are as many as 600.
(*Gegenbauer.*)

The auditory organs of the jelly-fishes are ranged around the margin of the umbrella, and are very numerous, in some genera running as high as 600, but in others from 60 to 80. The organ is more complicated in some than in others. In some it is a mere open pit or vesicle lined with cells, some of which contain otoliths, while others support auditory

hairs. Other medusæ have auditory organs in which the vesicle is closed and the otoliths reduced in number. In others the organ is a modified tentacle which is, in some cases, more or less completely enclosed in a cup-shaped cavity. The organ is supplied with otoliths situated at its apex. (Lubbock "Senses of animals.") In the crabs, lobsters and other crustaceans, the hearing organ is furnished with auditory hairs which are connected with the nerve. In most cases the ear is in the head at the base of the small antennæ, but in the *Mysis*, a genus resembling the Shrimp, the ears are in the tail. Hensen found that the auditory hairs of different length vibrated under the influence of sounds of different pitch. He "took a mysis and fixed it in such a position that he could watch particular hairs with a microscope. He then sounded a scale; to most of the notes the hair remained entirely passive, but to some one it responded so violently and vibrated so rapidly as to become invisible. When the note ceased the hair became quiet, as soon as it was resounded the hair at once began to vibrate again. Other hairs in the same way responded to other notes." The vibration of the hairs is mechanical and does not depend on the animal being alive. (Lubbock.)

The ear of the crustacean Cray-fish, is placed back of the eyes at the root of a pair of short branched antennæ. There is a cavity with a small entrance on top, surrounded by hairs, and closed by a membrane. Inside the cavity and nearly filling it is a sac nearly filled with fluid. In the bottom part of the sac is a little ridge (*crista acustica*) from which sprout a number of vertical hairs. Fine white threads, fibres from the auditory nerve, ramify on the ridge and communicate with the roots of the hairs. In comparing this simple auditory organ with the human ear the *sac* appears to correspond with our vestibular sac, the ridge supporting the hairs to our *crista acustica.* The auditory fibres begin, in both cases, at the roots of the hairs on the ridge. The mechanical action of the sense organ terminates in the same place in both cases and surrenders the stimulus to the afferent nerves. This point is the essential part of the ear in all cases. The additions made by long habit and selection to the ear of our inheritance—the semicircular canals with their ampullæ, the cochlea, with its three-story stairway, the basilar membrane with its keyboard of Cortis arches, the drum with its bony sounding post, the auditory canal and the ear flap, are so many improvements, more or less "modern" by which new and various properties of sound agitations have succeeded in making themselves felt by us, or the old properties more perfectly emphasized. Among the mollusks the ears are of a simple character. That of the Unio is shown in fig. 205. Simple as it is, the stone, the hairs, the cells and the nerve are present. Fig. 206 shows a little more perfect arrangement, as the ear of a free swimming Gasteropod, the Pterotrachea.

Here there is a sort of ear-drum covering the cavity in which is the stone, the hairs, the endolymph and the cells, connecting with the auditory nerve. This drum answers to our fenestra ovalis.

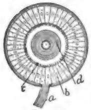


FIG. 205.

Fig. 205.—*Ear of Unio* (*Fresh water Clam*).
a.—Nerve. *b.*—Cells.
c.—Cilia. *d.*—Otolith (or ear stone).

In the sepia or cuttle-fish (a cephalopod mollusk) there is a cavity in the cartilage of the head in which there is a little membranous sac in which the fibres of the auditory nerve begin something equivalent to fig. 206. The development of the ear in this animal appears to be inferior to that of the eye in the same animal. The amphioxus, the present representative of the lowest type of the vetebrate, is destitute of ears of any kind.

The ear of the Hag-fish (myxine), of the order of the cyclostomi, consists of a single membranous sac which, however, is shaped like a tube bent into a ring. If we call one part of this tubular ring the vestibule, the rest of it would represent a semicircular canal. (The development of the semicircular canal as observed in the chick is as follows: From the original ear sac, a pocket-like process pushes out. In the middle of this pocket the two side walls opposite each other approach until they come together and coalesce, forming an island around which the un coalesced portion of the walls forms a tube, each extremity of which joins the original sac.) (Haeckel.)

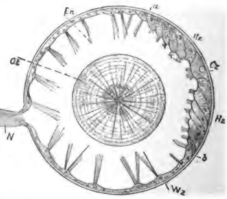


FIG. 206.—*Auditory Vesicle in section of a Mollusk Heteropod; Pterotrachea.*
a to *b.*—Receptive sensory cells answering to the drum called *Macula Acustica* (hearing spot).
Hz.—Cells in the same. *Cz.*—Central cell.
Wz.—Ciliated cells lining the inside.
En.—Space filled with fluid, Endolymph.
Ot.—*Otolith* suspended in same.
N.—Auditory nerve. (*Claus.*)

The Lamprey (Petromyzon), a near, but somewhat advanced relative of the Hag, has *two* semicircular canals connecting with the vestibular sac, which no doubt is the remains of the original simple sac. In the Rays, cartilaginous fishes, there are two canals quite circular and connected by ducts with the original sac or vestibule. This seems to be an unusual arrangement. The shark, a related animal, has the two canals in the usual form. (Huxley.)

In the Teleosteans, or ordinary bony fish, there are always *three* semicircular canals, offshoots from the vestibular sac. The sac contains a prominent *crista acustica*, and also otoliths, usually two in number, large and solid. Names have been given to these stones, the larger front one being called the *sagitta*, and that in the rear, *asteriscus*. This fish ear is within the cranium.

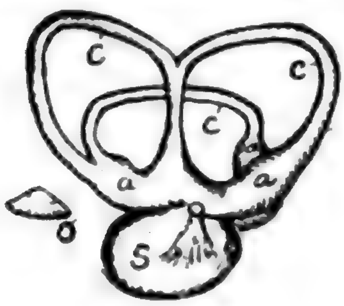


FIG. 207.

FIG. 207.—*Ear of Salmon.*
s.—Membranous Sac on the inside of which the Acoustic Nerve is spread out.
o.—Otolith also contained in Sac.
c c c.—Semicircular Canals.
a a a.—Ampullæ.

None of the fishes nor any of the animals below them in the scale of being, possess any tympanum, or tympanic membrane, or auditory canal (meatus), or ear flap, or tympanic bones. The membrane which covers their ear cavity bears the same relation to the inner ear that our fenestra ovalis does to ours. But this membrane is only a continuation of the outside skin of the fish and comes in direct contact with the water. In the course of the further development of the ear in the animals above the fishes, this sac, now called the *labyrinth*, together with the cavity containing it and the membrane covering the cavity, sinks deeper into the head ; bones are built around it and another membrane built across the mouth of the additional cavity so formed. This second cavity becomes the tympanum or drum, and a sounding post of cartilage or bone extends through it from the tympanic membrane to the membrane of the inner cavity, which membrane is now called the fenestra ovalis. The sounding post which is in one rod-like piece is called the *columella*. Where the tympanum is thus enclosed on the outside, there is a eustachian tube leading from it to the throat. Such an ear as this, with the tympanum level with the head, is possessed by most of the Amphibians. The eustachian tube sometimes is single and median at its entrance into the throat, and further back it forks, sending a prong to each ear drum. In some of the frog tribes, the highest of the Amphibia, there is also a fenestra rotunda, though it is not settled that they possess a cochlea. The ears of some toads are like those of the fishes, destitute of tympanum and columella. The ear of the Salamander (a batrachian) is concealed by the flesh and is destitute of a tympanum and columella, but has a little cartilaginous plate over the fenestra ovalis.

Coming up a step into the class of reptiles we find the second sac answering to our scala media present in all. But in some, as the Turtles, it is quite rudimentary while it is not coiled in any of them; although it may be slightly bent or twisted. There is also a fenestra rotunda which implies a scala tympani accompanying the scala media, the whole constituting a *cochlea*, except in the feature of the spiral twist, the circumstance on which the name is based. There is still no auditory canal or ear flap. The crocodile, however, has a pair of fleshy lips over his ear drum which are opened and closed at will. A few of the lower

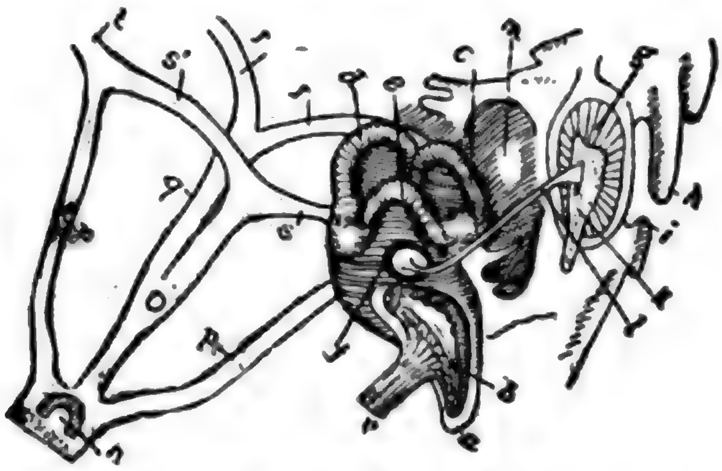


FIG. 208.—*Ear of a Crocodile.*

h.—Flap of Skin which can be closed down to the opposite fold, *i*, and shut the ear.
g.—Tympanic membrane or ear drum-head.
k.—A gristle representing the Malleus.
l.—The columella or *ear bone.*
f.—Fenestra ovalis (or vestibuli) with foot of the columella resting upon it.
m.—Tympanic cavity or drum.
c.—Anterior perpendicular Semicircular Canal.
d.—Posterior " "
e.—External or horizontal " "
v.—Cochlear division of Auditory Nerve.
a.—Apex of cochlea slightly bent.
b.—Double cartilaginous partition dividing the cochlea into two compartments, except at the apex where they unite.
n.—A valve partly closing the opening into the pharynx of the Eustachian tubes for both ears. Three branches depart from this place—*p* and *p'* to the left and right respectively, and a middle vertical one *o*, which sends off a branch *q* from behind in the median line.
s s'.—Branches of canals from *o* to a junction with *p* and *p'* at *t*.
r r'.—Branches of *q*. (*After Owen.*)

and retrograde families of the reptiles are destitute of the tympanum (Ophidia and Amphisbœnes). Others, as Turtles, Chameleons and the lizzard, Sphenodon, have tympanic cavities covered by the skin. In lizzards the tympanic cavities communicate by wide openings with the pharynx. In Crocodiles and Turtles these are narrowed down to eustachian tubes. The bone of the ear drum, extending from the fenestra ovalis to the drum head, or tympanic membrane when there is one, is simply a *Columella* (See fig. 208). When there is no tympanic membrane its outer end is buried in the muscles covering the ear.

Birds, being modified forms of reptiles, they possess ears substantially reptilian. There is, however, usually a short auditory passage outside of the tympanic membrane. The bone of the middle ear is usually only the columella—a single bone. There is no ear flap, but the ear is surrounded by a circle of feathers of peculiar formation.

The eustachian tubes of birds in proceeding from the two ear drums, first join each other, and then open into the pharynx by one median passage, like some of the amphibians already mentioned. The cochlea of

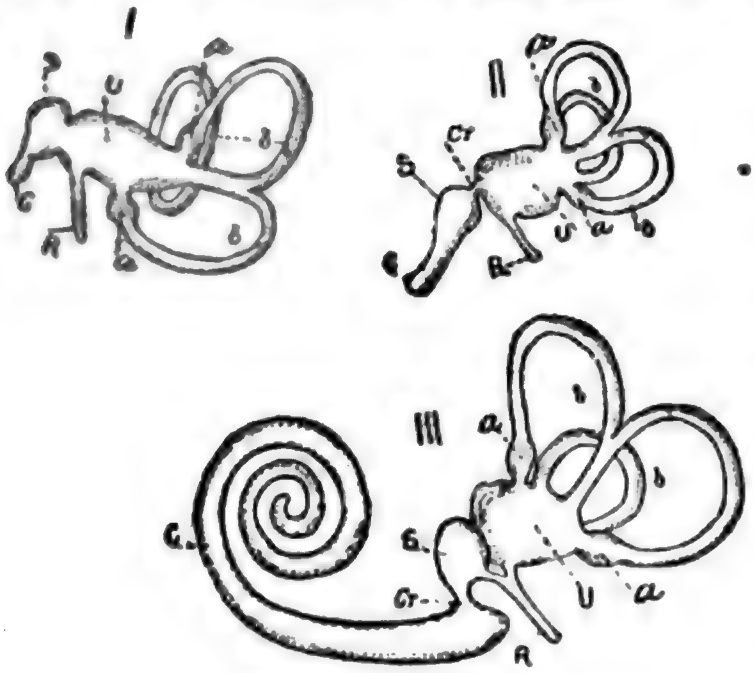


FIG. 209.—*Diagrams of Auditory Labyrinth.* (*Waldeyer.*)
I.—A Fish.
II.—A Bird.
III.—Mammal and Man.
s.—Sacculus.
u.—Utriculus.
c.—Cochlea.
Cr.—*Canalis reuniens.*
a.—Ampullæ.
b.—Semicircular canals.
R.—Acqueduct of the vestibule.

FIG. 209.

birds is only slightly twisted like that of the reptiles. The interior of their scala media is much less complicated than that of the higher mammals and does not possess the arches of Corti. In fact, these belong to the mammals alone. The other sac, however, the labyrinth, is amply developed in birds, and the three semicircular canals are large. The lowest of the mammals are, like the birds, derived from reptilian stock. And as they are close to the point of separation, in many particulars they resemble the birds, as they resemble the reptiles below them. Thus in the Monotremes the cochlea is only slightly bent upon itself, not coiled, as in other mammalia. The stapes bone is similar to the columella of birds. But the additional

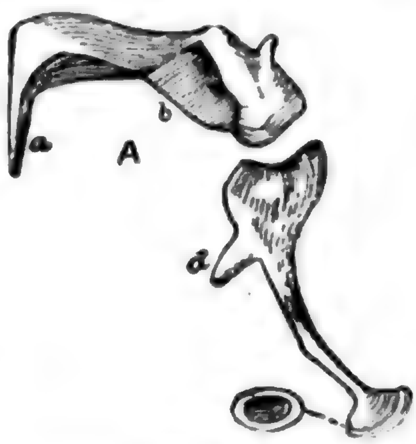


FIG. 210.
A.—*Ear bones of Perameles, a Marsupial.*

FIG. 211.
Stapes of Kangaroo, a Marsupial.

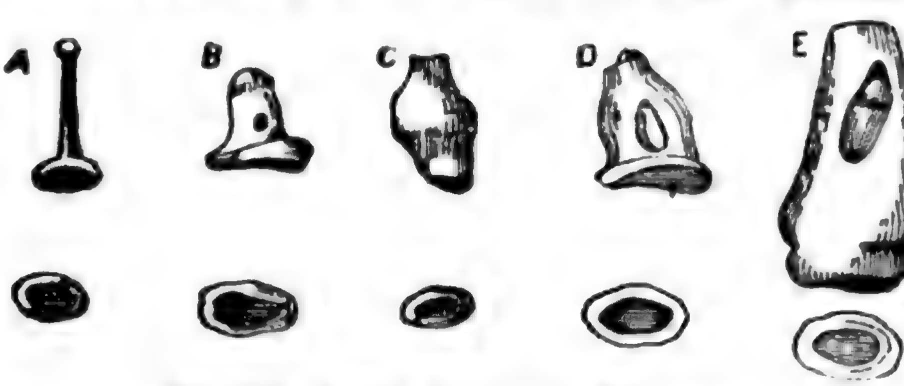


FIG. 212.—*Stapes of Aquatic Mammals.*
A.—Ornithorhynchus. *B.*—Porpoise. *C.*—Walrus. *D.*—Seal. *E.*—Manatee. (*Owen.*)

incus and malleus bones are already present, the three being the successors of the ancient reptilian columella. In all the mammals, above the marsupi-

als, the cochlea is spiral. In the Whale tribes and the Hedghog, the cochlea makes one and a half turns. In the Paca (a rodent) it makes *five* turns. In the apes and man it makes two and a half turns. The ear of man,

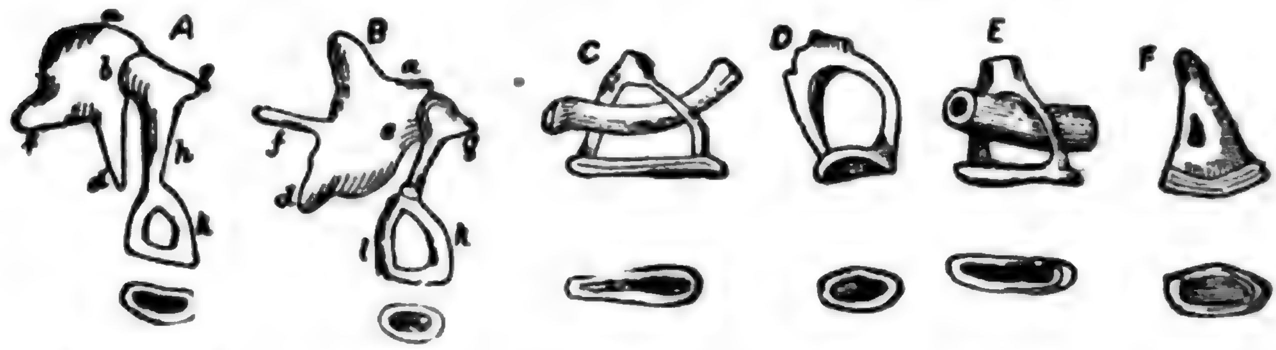


Fig. 213.—*Ear bones of* *A.*—Bat. *B.*—Shrew. *Stapes or Stirrup bone of* *C.*—Mole. *D.*—Hedgehog. *E.*—Marmot. *F.*—Sloth. Blood vessels running through *C* and *E*. The discs at the bottom indicate the shape of the foot of the stirrup. (*Owen.*)

while more discriminating as to musical sounds than that of most other animals, is far behind many of them in the acuteness of its perception and its sensitiveness.

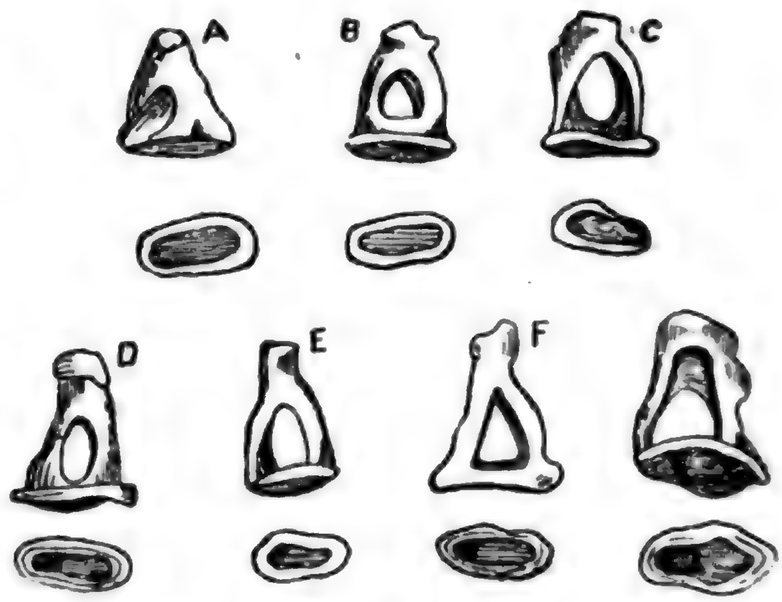


Fig. 214.—*Stapes of Ungulate Mammals.*
A.—Hippopotamus. *D.*—Horse. *F.*—Rhinoceros.
B.—Hog. *E.*—Tapir. *G.*—Elephant.
C.—Musk-ox.

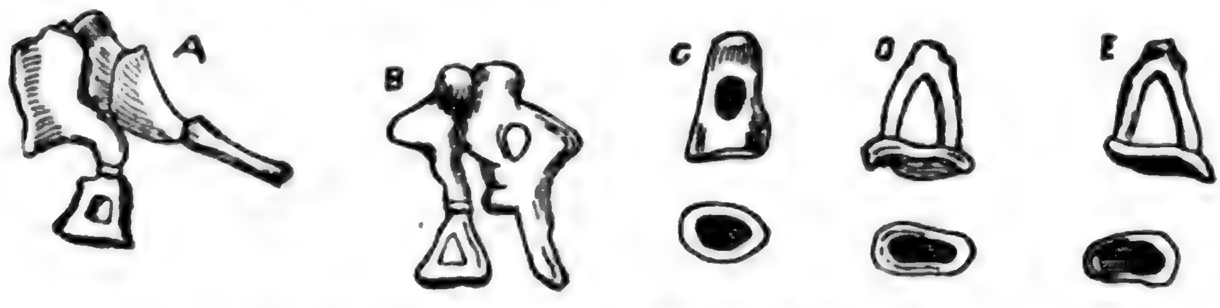


Fig 215.—*Stapes of Carnivorous Mammals.*
A.—Seal. *B.*—Otter. *C.*—Bear. *D.*—Dog. *E.*—Tiger. (*Owen.*)

The eustachian tube is the remains of the first gill slit in the embryo. In the primitive cartilaginous fishes, this gill slit remains open, and is a blow-hole leading from the back part of the mouth. In the further development of the ear in the higher vertebrates, the gill arches, before and behind this gill slit, namely, the first and second, originate the parts of the middle and external ear. The tympanic membrane is formed by the coalescence of the sides of the gill opening at a certain point. Whatever is left of the opening, outside of the point at which this coalescence takes place, becomes the meatus, or external auditory canal. Of the part left inside

of this point, the forward end next the mouth becomes the eustachian tube, while the rear end, next the tympanic membrane, is the tympanic cavity or drum. The hammer and anvil bones are developed from the first gill arch, the stapes (stirrup) from the second. (Haeckel.)

The division of the musical scale into seven intervals appears to have been purely accidental, and has been transmitted with its variations and growth from the ancients. Our adherence to the present scale, and especially the readiness with which children take to it, shows the nature of an instinct to be *hereditary* acquirement, for it is not founded in any natural necessity but in a chance habit. (See History of the Scale in *Blaserna's* Theory of Sound.) Octaves are natural chords it is true, but they are chords in a geometrical ratio, while equally true chords go by arithmetical ratios, and would be at least as natural. Vocalization depends on the auditory sense. People who are born deaf are also dumb, unless carefully trained, although their vocal organs may be all right. In like manner the perfection of musical accomplishments depends on the quality of the ear. A great many birds not only have one or more songs of their own, but are able to learn the songs of others, so that they must be reckoned to possess a discrimination of sounds, and that without the organs of corti, as stated above. It is probable that the function of pitch may be connected with the cross fibres of the basilar membrane (fig. 197), their progressively increasing length from bottom to top corresponding with a descending musical scale. A number of other animals besides birds and men possess musical talents. An ape of the Gibbon family produces an exact octave of musical sounds, ascending and descending the scale by half tones. A good many of the

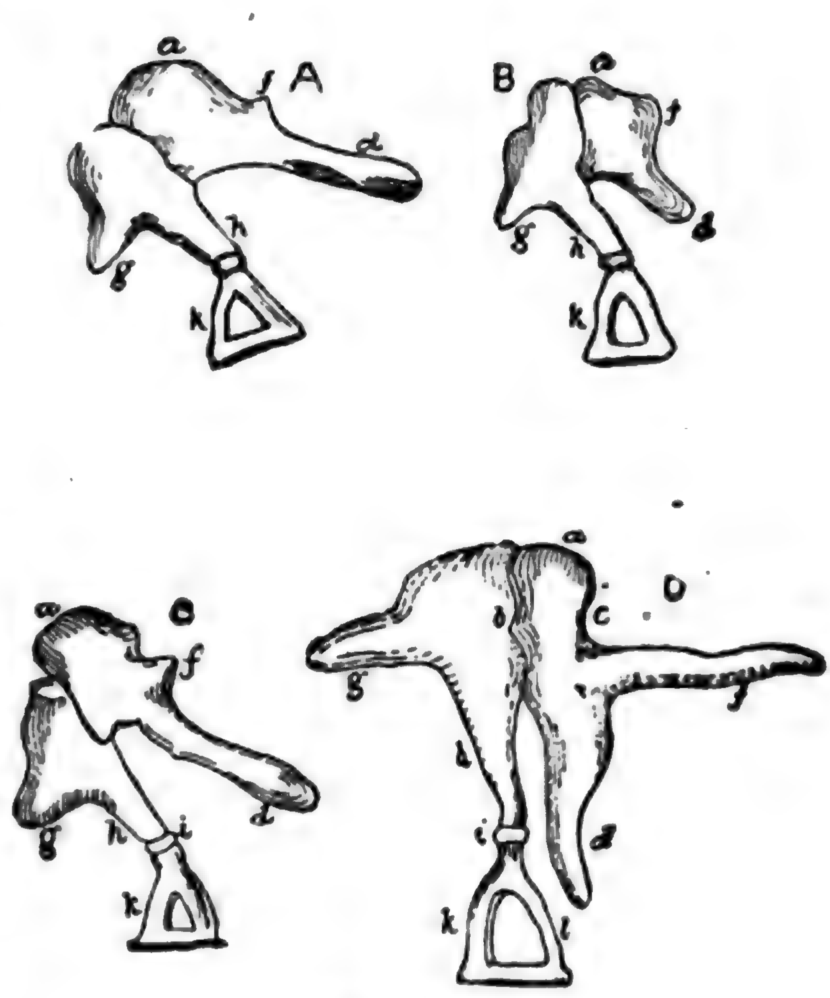


FIG. 216.—*Ear bones of Monkeys compared with those of Man.*
A.—Lemur.
B.—Cebus.
C.—Cercopithecus.
D.—Man.
Observe the progressive evolution of the "process" *f*.

FIG. 216.

rodents, especially mice, have an appreciation of music without being able to make it themselves. But there are some possessed of very respectable musical powers. Mr. Lockwood, in the American Naturalist for Dec., 1871, gives an account of a musical vesper mouse, or wood mouse (*Hesperomys Cognatus*), which came into his possession. This little animal did most of her singing at night, and she had several songs in the major key of B. "Her soft clear voice falls an octave with all the precision possible." On one occasion she sang continuously for nine minutes, during which time she performed all her regular tunes, adding new and beautiful variations. One measure was so silvery and soft that Mr. L. said to a lady who was listening that, "a canary able to execute that would be worth a hundred dollars." Her pauses between the roles did not, on this occasion, exceed a second. She often kept up her singing while eating, and while in her revolving wheel. She had a particular song for the wheel. Mr. L. also mentions a common mouse owned by a friend of his, which was a rather indifferent singer. He states that there have been singing rats, and that several varieties of squirrels are capable of musical sounds. Mr. W. O. Hiskey, of Minneapolis, also reported to the American Naturalist for May, 1871, an account of a musical prairie mouse, *Hesperomys Michiganensis* (as supposed). He found him in a closet in an overshoe filled with pop-corn which he had stolen from a basket near by. He was singing something like a canary bird. Mr. H. observed him for ten minutes not more than four feet away. "His song was not a chirp, but a continuous song of musical tone, a kind of *to-wit-to-wee-woo-woo-wee-woo*, quite varied in pitch." He did not succeed in capturing the little musician.

CHAPTER XLIX.

SMELL.

The cavities of the nose, mouth, &c , which have been formed by invagination or a doubling in from the outside, are lined with a continuation of the outside skin, which in its interior position acquires some slight modifications and receives the name *epithelium.* The front end of the brain rests upon a portion of the skull called the ethmoid or sieve bone (or sometimes the *cribriform* bone, which means the same). This bone in front is composed of many fragile laminæ or plates separated and forming numerous cavities. It articulates above with the *frontal* bone which bounds the front end of the brain and forms the forehead. The front walls of this bone consist of two layers considerably separated from each other, forming two large cavities, one on each side of the root of the nose, and called frontal sinuses. These open below and con-

nect with the cavities in the ethmoid bone. There is also an opening in the upper jaw bone on each side called the Antrum of Highmore, and these are connected with the ethmoid cavities and the large cavities of the nose. Besides these are the lachrymal passages leading from the nasal passages to the tear glands; and lastly the pharynx is reached from all these cavities through the rear doors of the nasal openings, and from that, access may be had with the cavity of the mouth and the eustachian tubes leading up to the ears. The walls and projections of all

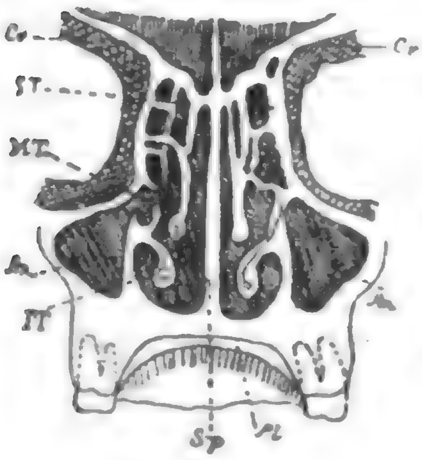


Fig. 217.

Fig. 217.—*Vertical Cross-section of Nose* from base of brain to the palate.
Cr.—Cribriform bone on which the base of the brain rests.
Pl.—Palate.
Sp.—Septum or cartilaginous partition between the two cavities.
S T, M T, I T.—Superior, Middle and Inferior Turbinal Bones.
An.—Antrum; Cavity in Upper Jaw Bone.
The olfactory nerve filaments are distributed to the surface of the septum and upper two turbinal bones.

these openings are covered with this epithelium. The cavities on the two sides of the nose do not directly connect with each other, being separated by a cartilaginous wall or septum. The back or upper part of each of the nasal cavities is divided into three passages (meatus) by three scroll-shaped bones called the turbinated bones (from *turbo*, a top). These are placed one above another, attached to the outer side of the cavity and presenting a convex side toward the median septum.

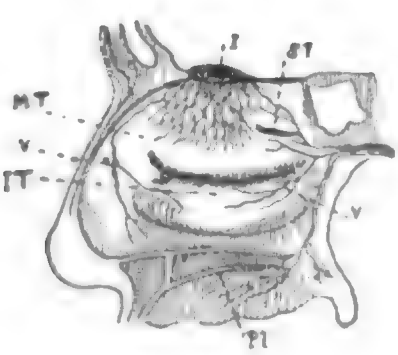


Fig. 218.

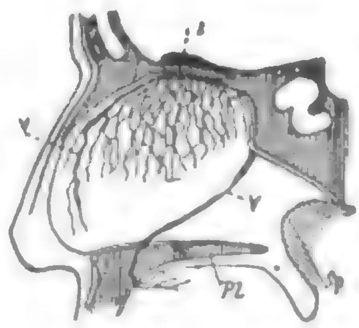


Fig. 219.

Fig. 218.—Vertical section of right nasal cavity showing its outer wall.
Fig. 219.—Inner wall of the left nasal cavity or left side of the middle partition of the nose; references same in both.
Pl.—Palate—roof of the mouth.
V V V V.—Branches of the Fifth nerve or Trigeminum.
I.—The *Olfactory nerve* lying on top of the cribriform or ethmoid bone through holes in which the numerous branches pass to the nasal cavities.
St, Mt, It.—Superior, Middle and Inferior Turbinal Bones.

The part of the epithelium which lines the nasal cavities is called the pituitary membrane and sometimes the Schneiderian membrane. The part of this membrane which covers the middle and upper turbinated bones is the portion which, in man, is differentiated into the organ of

smell. The ends of the olfactory nerve are distributed to this part of the membrane only. They come directly down through the roof bone of the inner nose called the cribriform plate of the ethmoid or sieve bone, which also at that point forms the base of the skull. On top of this plate, inside the cranium, lies the olfactory bulb or lobe, which in man constitutes a large ganglion or expansion of the olfactory nerves. From the under side of this olfactory lobe the fibres of nerve pass through the holes of the cribriform plate and spread themselves over the pituitary membrane.

In the nasal cavities the membrane appears formed of two layers intimately united. The one in contact with the bone is fibrous; the other is free at one surface. The latter is a mucous membrane on which there are to be found small papillæ and mucous follicles that open into the cavity of the nostrils. On penetrating the maxillary, frontal, sphenoidal and ethmoidal sinuses, the membrane becomes very thin, transparent, less vascular, and seems reduced to its mucous layer. (Dunglison.)

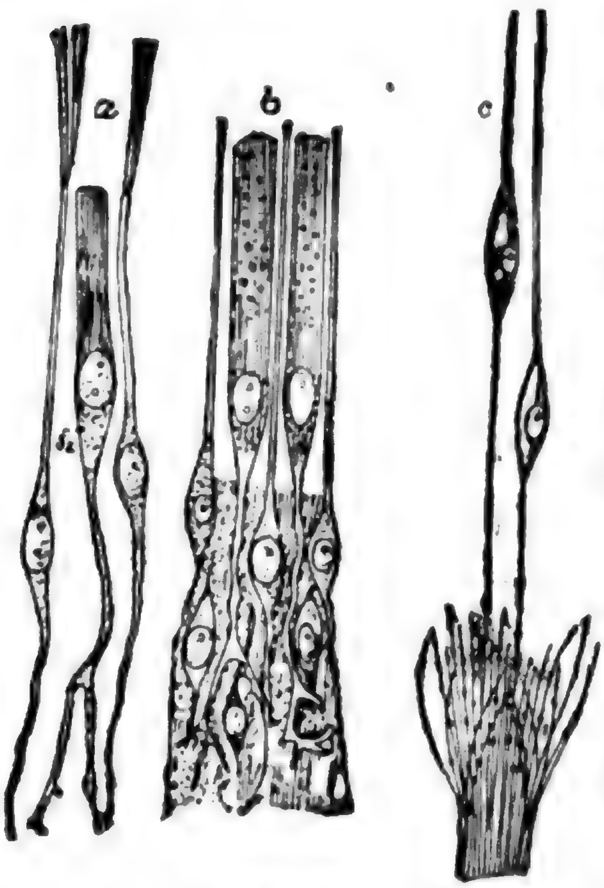


Fig. 220.

Fig. 220.—*Rod-shaped sense cells from the Organ of Smell.*
a.—From the Frog.
b.— " Man.
c.— " " Pike-fish.
Sz.—A supporting cell between two ciliated rod cells which probably are the active agents to convey the stimulus to the cells and nerve fibres below. The top ends in all three are the parts directly exposed to the irritation of odorous particles. (*Todd & Bowman.*)

The inferior meatus or channel below the inferior turbinal bone in each nostril is an air passage, but not concerned in the olfactory sense. The mucous membrane in this part of the nasal cavities is covered with epithelial cells which are furnished with cilia or minute hairs. In the olfactory part of the cavities the cells of the membrane present a broad end to the surface, but become attenuated when traced inwards toward the underlying network. Between them we find *long, rod-like filaments*, which in their lower part swell out into a nut-shaped expansion and then are prolonged into a fine fibre toward the interior. (Bernstein.) These fibres are lost in the network of nerve fibres and probably connect with them and thus with the olfactory nerve. Very fine hairs have been found upon these rods in some animals. The cells receive the contact of the odorous substance as the organs of smell, and the nerve fibres are the vehicles of the irritation as in the other senses.

The sensation of smell is strongest when the irritation is freshest, and it is assisted by "sniffing." Our sensibility in all sensory irritation is more acute when the irritation is sudden, either in beginning or ending. A sound like the hum of a mill when first begun will arouse our attention, but if continued monotonously will make us drowsy. So of smell; the first irritation awaking attention, while a continuation of it obscures it. And its revival requires the sudden renewal of sniffing.

Smell is the most delicate of all the senses; and we can by it gain a knowledge of substances that we cannot begin to see, taste or touch. We can smell three one hundred millionths ($\frac{3}{100\,000\,000}$) of a grain of musk. No chemical reaction, nor even spectrum analysis, can detect what we can smell, and yet the spectrum can recognize $\frac{15}{1\,000\,000}$ of a grain.

The odor of rosemary is perceived at sea off the coast of Spain before the shore is in sight. A grain of musk will scent a room a year. Haller kept papers scented 32 years with one grain of amber—each square inch of surface of paper was impregnated with $\frac{1}{2\,891\,064\,000}$ part of a grain and perfumed besides a stratum of air one foot deep, for 11,600 days or about 32 years. (Papillon.)

The delicacy of smell even in our race is often very refined. A certain woman foretold storms several hours in advance by the sulphurous odor, probably due to ozone in the air. A deaf mute is on record as being able to distinguish various plants by the odor alone. But many of the lower animals are far ahead of us in the delicacy of this sense. A hound can smell an animal entirely out of sight. Deer, Buffalo and other game can scent the hunter, if on the windward side, quite beyond rifle range. A dog can follow his master and pick out his particular odor in a crowd of men, and he can follow any animal by the odors clinging to its tracks hours after they are made. Beavers and many other animals possess similar faculties. The Lemur possesses an excellent smelling organ. Birds of prey can often smell further than they can see. Crows will scent a carrion at the distance of a league. Reptiles and fishes have large olfactory lobes, but since the vehicle of odorous particles in this case is water, and come in solution instead of a gas, the sense with them must be somewhat akin to our sense of taste.

We can readily see that our own smell organs would behave very differently, perhaps be entirely subverted if immersed continuously in water, while our taste organs would probably not be at all impaired. The whale tribes, which are modified from land mammals, have to a great extent lost the sense of smell. Porpoises have no olfactory nerves at all and no turbinal bones. Walruses have small olfactories.

Many essential oils of plants are agreeable in their odors, the reason of which is not obvious. They are combined for use in cologne water, &c.

Others smell bad—many hydrogen compounds, &c.: Sulphuretted hydrogen, phosphoretted hydrogen, arseniuretted hydrogen, bisulphide of carbon, and other volatile hydrocarbons; also many compound organic bodies, especially those formed by organic decomposition. In general, bad smelling things are repugnant to health, although all noxious substances do not give this warning. The gases which have a great tendency to combine and to react rapidly upon organic tissues are odorous. Sulphuretted hydrogen decomposes the blood, turning it black, and chlorine, iodine, bromine and ammonia rapidly destroy organic substances. The vapors, alcohol, ether and chloroform, all rapidly act on organic tissues. The gases which are not odorous act slowly or not at all chemically on organic tissues, as hydrogen, carbonic acid, oxygen, except when oxygen is in its active state, ozone, and then it *has* an odor. A great many smells of food, &c., are very agreeable when we are hungry and not when we are full. (Bernstein.)

This sense, like all the others, is subject to hallucinations and illusions which arise from the fact that the *nerves* can be stimulated by other agitations than those coming through the sense organ. The organ itself can be impressed only by the forces which have differentiated it, or by some forces closely akin to them. But the conveying nerve fibre (as well as the corresponding brain cell) receives every stimulus as if it came from its own proper sense organ. If, therefore, an olfactory nerve fibre, differentiated to convey the smell of wine for example, should be touched or stimulated at a point between the pituitary membrane and the brain, the stimulus would pass into the brain as a veritable odor of wine, and unless some other sense should expose the deceit, the illusion that wine had actually been smelled would be complete. Disease or injuries of the olfactory bulb or of the anterior lobe of the brain have been known to produce delusion of smell. A case is recorded in which a man after a fall from a horse always fancied that he smelled a bad odor. (Neil & Smith.) Sometimes temporary delusion may arise from a revived memory of an odor. The brain cells devoted to the perception of that odor become erected abnormally and produce the false perception. A certain woman smelt the odor of musk whenever she saw a well dressed woman passing; and smelt tobacco when a man went by. Another could not bear the smell of the rose and became sick upon seeing an artificial one, the false sense of the odor being arroused by the imagination. (Papillon.)

The mode of action of the sense as generally explained is simple enough. Odorous substances are those that cast off into the air infinitely minute particles of their substance. These particles passing into the nasal channels with the inhaled oxygen of the air come into contact with the pituitary membrane and stimulate or excite it. This stumula-

ion is there converted into a nervous current which passes along the olfactory nerve fibres into the brain. It is essential that the body to be smelt be soluble, so that it can be taken up by the mucous fluid of the pituitary membrane. The essential action seems to be first the production of chemical action in the cells of the pituitary membrane, which then gives rise to the electro-nervous current.

The sense of smell is a very ancient sense. In some of the Turbellariæ, or Gliding-worms, there are olfactory organs consisting of two mere indentations or pits above and behind the mouth, but not connected with it. This arrangement must have in ancient times been persistent through a long line of animal forms, now extinct, which formed the connection between worms similar in construction to the present gliding-worms, and the lower vetebrates of the equivalence of the selachian fishes. The selachian fishes are by no means the lowest living vertebrates, but the cyclostomi (Hags and Lampreys), the amphioxus and the ascidian larvæ, which constitute lower vertebrate forms, have but a *single* olfactory organ in the middle, and so they would seem to belong, not to the direct, but to a collateral line. (The single nostrilled animals are, however, bilateral as to eyes, ears and gill pouches.)

In the stage of development following that of the selachian fishes, the olfactory furrows become connected with the mouth, as the organs appear permanently in some of the higher selachian fishes. There is, as yet, no closed tube, but an open gutter, one end of which extends to the corner of the mouth. Later, as the gutter sinks into the face, the opposite edges reach over the channel towards each other, finally coalescing and forming a tube, one end of which pierces the lip into the mouth cavity, while the other is open forward. In this stage the organs are like those permanent in the mud-fishes (dipneusta).[1] In most fishes the nasal organs never become tubes, and are never connected with the mouth. They are merely superficial sacs lined with the continuation of the outer skin which is differentiated into sensitive mucous epithelium. In the progressive evolution of this fish nostril, the membranous lining becomes wrinkled into folds or ridges, which, in some cases, radiate from a center, in others are arranged in parallel direction on each side of a central band. In this way a greater surface of sensitive membrane is exposed to the action of odorous particles, and those fishes possessing the greatest complication of these folds have the most acute sense of smell (Agassiz). These folds call to mind the membrane covered turbinated bones of the human nose, in which the same end is accomplished in a very similar way. In some fishes the first pair of nostrils are reinforced by a second pair, giving them four in all instead of two. In the further development of the embryonic nasal cavities, the ends of the

[1] The dipneusta are rather in advance of this stage, their nostrils opening somewhat behind the lips.

tubes which open into the mouth cavity are gradually carried further inward, a process which necessarily leaves a constantly increasing plate or partition between the mouth and the nasal cavities. This separating plate is the palate or roof of the mouth; the nasal cavities opening behind it into the back part of the mouth, and lastly behind the mouth into the pharynx. The different stages of this progressive movement of the inner ends of the nasal cavities successively represent arrested and stationary conditions in the amphibia, the reptiles, the early mammals, and the higher mammals, in the order in which they are here named, attaining their complete development in the higher apes and man. The sense of smell in man is less highly developed than in many lower animals, and appears to have become, to some extent, reduced and rudimentary. In most lower vertebrates, the olfactory lobes are much larger in proportion to the rest of the brain than in adult man, and this same is true of the human foetus. The sensative surface of the pituitary membrane is in man much smaller than the whole membrane. The large amount of functionless surface in the inner nasal cavities would seem to indicate that the habits of the animal ancestors of the race differentiated and handed down to us a larger olfactory apparatus than we at present use. The acuteness of the sense can be vastly increased in anyone by persistent habit, and, in all probability, if there were any occasion for it, the race could, by use, become as acute in the sense as dogs and other higher mammals. It is recorded that persons have become sufficiently sensitive to recognize other persons by their smell, and in one case a person could pick out his own clothes from among many others by this sense. (Neil & Smith.)

The eccentricities of the sense are remarkable. One man was insensible to all odors except that of a manure heap or rotten cabbage; another could not perceive any smell to vanilla; another could not perceive the scent of mignonette. The effects of odors on different persons are likewise very different. The scent of apples and roses have been known to be very disagreeable to some persons. Others, again, are pleased with assafœtida, valerian-root, the scent of old books, or the smell of a dunghill (Papillon). Some people like the odor of musk, which others detest. Many odors are agreeable or beneficial in a small amount which are hurtful or disagreeable when very strong; and habit often reconciles the sense to what is at first almost intolerable. Habit, or use, is indeed responsible for every modification of the sense of whatever kind. There is, in fact, the same sort of differentation of the epithelial cells into sensitive organs in this case, that we find in the retina of the eye and the crista acustica and scala media of the ear. The modified cells and "rodlike fillaments" of the pituitary membrane are the peers of the "rods and cones" of the eye, and the arches of Corti, and the auditory

hairs of the ear. The multitude of volatile particles borne through the air constitute, with their chemical affinities, a power of the environment, as able, under proper conditions, to stimulate, and consequently to modify, organic cells, as those other modes of energy we call light and sound.

As the different tones of vibration have, in the case of the eye and ear, differentiated a separate organ for each tone, so *each* odorous stimulus that is perceived by any pituitary membrane, has so altered some of the cells on that membrane that they are moved and agitated whenever assailed by that particular stimulus, and become more pliant and responsive the oftener the stimulus is applied. There must, therefore, be a separate set of the cells and "rodlike filaments" for every single odor that can be perceived. The number of these is not probably so great as the number of musical tones and noises that can agitate the ear. Many of the odors are compound, and each of the composing elements will seek out the cells and filaments which it is competent to agitate, and these separate agitations, reunited in the brain cells, will form there the compound agitation necessary to a perception of the compound odor, just as the rods and cones of the retina analyze a compound ray of light and restore it again in the optic cells of the brain. It is generally agreed that smell is a sensation arising from chemical reaction between the particles of odorous matter and the mucous fluid of the pituitary membrane. The agitation caused by this union communicates itself to the pituitary organs, and is there arrested as chemical action, but continued along the nerve fibres as nervous electricity. If this chemical action were able to affect all the cells and filaments alike, there could be no discrimination of odors but all would be alike. The reason why they are not all acted upon alike is because the different sorts of chemical action result in the formation of different *sorts* of molecules on the face of the pituitary gland. This cannot well be otherwise. The following essences all differ in smell, and some of them greatly; viz., Lemon, Bergamot, Neroli, Juniper, Lavender, Cubebs, Pepper and Gilliflower. It is not possible, therefore, that they all agitate the same cells of smell, yet all these essences are chemically precisely alike, their molecules all being composed of ten atoms of carbon and sixteen of hydrogen (C^{10} H^{16}). These compounds are called isomeric, and chemists account for their differences by assuming that the molecule of each one has its twenty-six atoms arranged in a different position with regard to each other, and that, therefore, the only difference consists of different *shaped* molecules.

Oxygen exists in more than one state. In its common state, as it is ordinarily mixed in the air we breath, its molecule is composed of two atoms, and it is odorless, as all know. But electricity may cause some

of it to enter another state in which it is called *ozone*. In this condition its molecule is composed of *three* atoms, and is necessarily of a different shape, and in this condition it can be smelled, the odor being similar to that of sulphur. It is therefore established that in this case the shape of the molecule alone determines the potentiality of the substance to agitate the pituitary cells. In the other cases as no difference can be detected or suspected in their molecules except difference of shape, it seems reasonable to conclude that the shape alone of each molecule involves the quality which is characteristic of its odor.

Sometimes one odor is able to neutralize or disguise another. This is doubtless due sometimes to the chemical action of the two odors upon each other and the mucous fluid of the pituitary membrane, the triple action resulting in a molecule differing from one which might be formed by the action of any two of the three. At other times each odorous body might make its separate impression on the brain cells; but one of them of such overpowering intensity as to cause a greater erection of the brain cells affected by it, and consequently to arouse consciousness exclusively towards it; just as a person suffering a great pain from one part of the body may be quite oblivious to a little one coming from another part. A game-keeper once apologized for the failure of his hounds to follow the game by declaring that the scent was overpowered by "them *stinking* violets." (Punch.)

CHAPTER L.

TASTE.

The organ of taste consists of a portion of the outer skin, which during the development of every individual is inverted or invaginated by being pushed in from the outside, as it were, during the formation of the mouth. It is therefore simply a specialized or differentiated portion of some of that part of the external skin which after becoming internal is called *epithelium*. In the case of this organ, and that of smell, there is no detachment or break in the continuity between the outside skin and the epithelium, but they grade one into the other. In the case of the eye and ear organs, they too are equally differentiated from the outside skin, but in the course of their evolution they have finally become detached from it and are no longer continuous with it, but are isolated sacs.

The tongue is the principal organ of taste. It is covered with the same epithelium which lines the cavity of the mouth, and the cavities mentioned in last chapter in connection with the sense of smell. The tongue is an organ exposed to a very large amount of stimulation and

consequently excited to a high degree of activity. It has therefore become highly differentiated. The tip of it is the most delicate touch organ we have, surpassing even the fingers; while a part of the rest of the surface is also sensitive to taste impressions. The ultimate organs

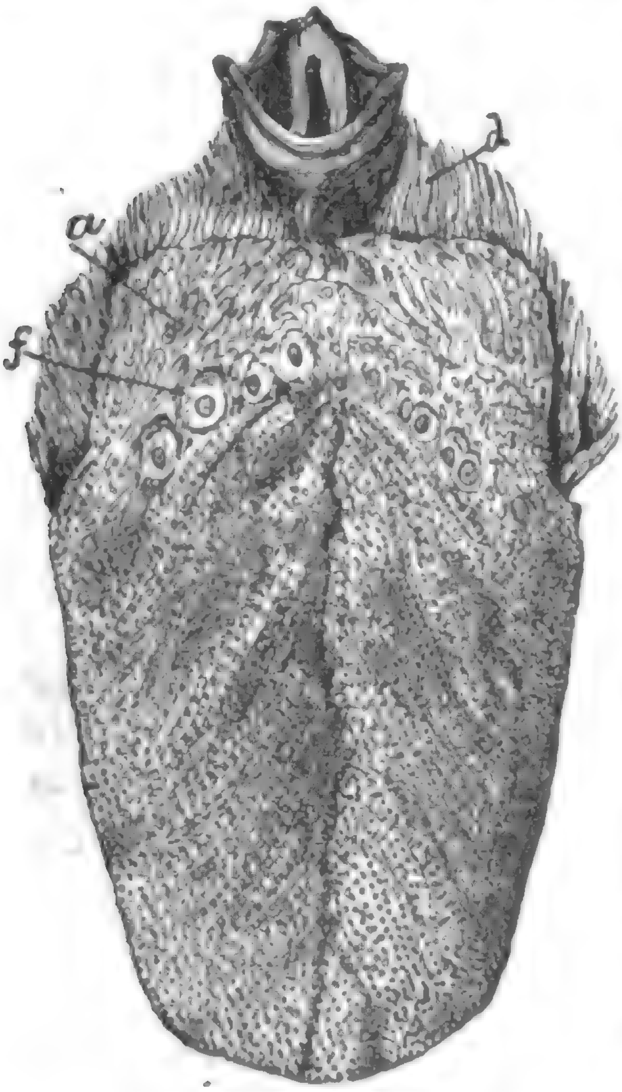


FIG. 221.

FIG. 221.—*Human tongue showing the top or Dorsum.*
d.—Smooth mucous surface at the root of the tongue, about half an inch long.
a.—Glandular area.
f.—Eight fossulate papillæ arranged in chevron form. Sometimes there are ten in man and sometimes only six or four.
(*After H. H. Salter.*)

of these functions are called papillæ. The number of the papillæ on the surface of the tongue is very great, and they are of three or four different sorts. About a half an inch in length of the root of the tongue is a smooth mucous surface covered with follicles for secreting a mucous fluid which aids in lubricating the food for swallowing, like the follicles of the palate lips, &c. In front of this area and arranged in the form of a chevron with its apex pointing in ward, is a row of very large cells, usually eight in number. Each of these is surrounded by a ditch, and on that account they are called circumvallate or fossulate papillæ (see fig. 222).

A second sort of papillæ are those called *fungiform*. They are scattered about the top and along the edges of the tongue. They are of a whitish tint and consist of rounded heads on top of short stems like mushrooms, hence the name *fungiform*.

FIG. 222.—*Section through the Large circumvallate or fossulate Papilla of the Tongue.*
a.—Top.
p.—Pedicle through which the nerves and vessels enter.
b.—Ditch.
c.—Scolloped margin of same.
t.—Taste buds.

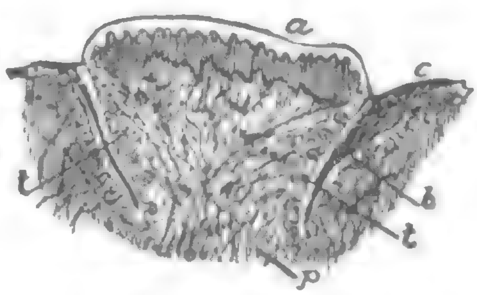


FIG. 222.

These and the large circumvallate papillæ are the main organs of taste. The third sort of papillæ are situated chiefly in the central part of the tongue. They are conical in shape, and are named the pyramidal or *filiform* papillæ. Those of the third species are the most numerous.

The filiform papillæ subdivide into at least two varieties which grade into each other, one sort are *conical*, as shown in fig. 224, and the other is cylindrical and has a brush of filaments on top, each of which is covered with scales. These filaments appear to be something in the nature of cilia, and are said to be "protective" and "portative." The conical sort are mainly organs of touch, while the mushroom or fungiform sort, and the large circumvallate ones are the true organs of taste. The gustatory branch of the 5th nerve supplies the fungiform, conical and filiform papillæ, while the glosso-pharyngeal supplies the fossulate papillæ, and the mucous tract behind. (*Owen.*) Experiments have shown that animals lose their discrimination of taste when the glosso-pharyngeal nerve is cut, for they will then eat disgusting food which, in their normal condition, they would reject. Very minute investigations into the structure of the taste papillæ by Loven and Schwalbe have shown that in the epithelium of these papillæ there are many bud-like groups of cells with which the ultimate fibres of the glosso-pharyngeal nerve are connected. These cells have been termed "taste buds." In man they are shaped like a flask, in some other animals they are more slender. "In the

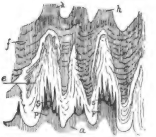


FIG. 224.—*Conical Papillæ of the Tongue.*
a.—Basal Membrane.
p. Body of the Papilla or "Process" on which rise the tactile papillæ.
f.—Superficial layer of epithelium.
e.—Lower layer of epithelium.
n.—The points from which the filaments project. (*Hyde Salter.*)

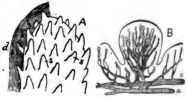


FIG. 223.—*Fungiform Papilla of the Tongue.*
A.—Body of one primary papilla covered with secondary papillæ *s*; and epithelium *d*.
B.—Section of same—*a* artery; *v* vein. (*Todd and Bowman.*)

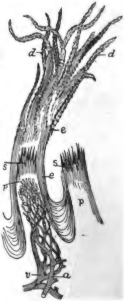
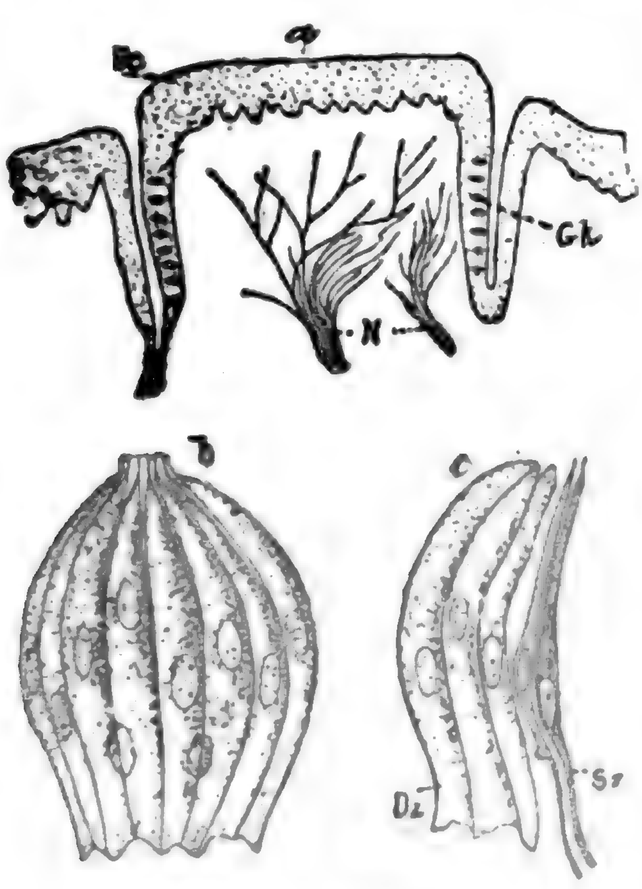


FIG. 225.

FIG. 225.—*Two Filiform Papillæ of the Tongue, one with epithelium, the other without.*
p.—Body of the papilla.
s.—Secondary papillæ springing from the primary ones.
e.—Epithelium laminated below.
d.—Filaments springing from it covered with scales, the excess of which constitutes the "fur" of the tongue.
a.—Artery. *v.*—Vein. (*Todd & Bowman.*)

dog they are $\frac{72}{1000}$ of a millimeter in length and $\frac{9}{100}$ in breadth. In the pig the number is estimated at 9,500, in the sheep at 9,600, in the rabbit at 1,500, in the cow at 35,000. In man they almost touch each other on some parts of the tongue, and their number is very great."[1] According to Landois there are no taste buds in reptiles or birds; while they are numerous in the mouth of the *tadpole*, and the tongue of the frog is covered with something like a gustatory epithelium. They are also to be found in the mouth of the Carp and Ray.

In addition to the tongue, the jaws and soft palate of the mouth are found to be possessed in some degree of the sense of taste. While this sense is not so delicate as that of smell it is often extremely fine. We can distinguish the taste of one part of sulphuric acid in 1,000 parts of of water. A drop of this solution on the tongue would contain $\frac{1}{2000}$ of a gramme ($= \frac{3}{400}$ of a grain). Chemical analysis could hardly distinguish this. (Bernstein.) In very many cases this sense is reinforced by that of smell. And it often happens that the flavor of an article cannot be recognized if the nose be closed so as to shut off the co-operation of the other sense.



FIGS. 226, 227, 228.

FIG. 226.—*Transverse section through a circumvallate Papilla from the tongue of a Calf.*
Pc.—Papilla.
Gk.—Taste Buds in its side.
N.—Nerves.

FIG. 227.—*b. Isolated Taste Bud from the lateral Taste Organ of a Rabbit.*

FIG. 228.—*c.* Isolated supporting cells *Dz*, and sense cells *Sz* from the same.

As in the sense of smell, an article to be tasted must be soluble, otherwise it is only touched by the tongue, not tasted. The taste of anything is very much intensified if it be moved over the surface of the tongue. In this respect this sense resembles both smell and touch; smell being intensified by "sniffing" or violently dashing the odorous particles against the pituitary cells, and the sensation of touch greatly increased by moving the touch organs over the object. When the papillæ are in action from the presence of a savorous body they become erected and swollen so as to produce a roughness of the surface of the tongue. Taste is a chemical sense, like smell. The body to be

[1] Lubbock Senses and Instincts of Animals, 19.

tasted, or some of it, must be dissolved by the fluid saliva and mucous of the mouth, and the molecules of the compound thus formed produce, by their contact with the taste papillæ, an action which is converted into a nervous electrical movement toward the brain cells. The theory arrived at in the case of smell, that separate organs exist for every odor whose sense is conveyed to the brain, applies equally in the case of taste and for the same reason.

According to Papillon the unassisted organs of taste are capable of only four primitive and original sensations; viz., sweet, sour, salt and bitter. If the organs of the sense of smell be out of order or closed up, these four will constitute the sum of taste. Various mixtures of these would give a great variety of tastes, and this variety is greatly increased as well as rendered vastly more refined and delicate by the co-operation of the sense of smell. If this is correct we need not suppose more than four kinds of taste buds.

Chemical compounds of very different nature have similar taste. *Acetate* of lead is sweet, while sugar, which is also sweet, is composed of carbon, hydrogen and oxygen. On the other hand, quinine, sulphate of magnesia and others which differ entirely in their composition have a bitter taste. Sweet taste is the opposite of sour and bitter, and the two last may be overcome or smothered by the former—either as if the sensations in the brain cells interfered with and mutually destroyed each other, or as if chemical action of the two substances in the presence of the saliva of the tongue produced a new molecule having a neutral or a compromise flavor. A saline taste cannot be mitigated by sweet. After tasting a bitter or saline substance, pure water seems sweet, because the water dissolves and removes the cause of the bitter taste substituting a merely negative taste which by contrast appears the reverse of the positive taste. It is a subjective sensation existing only in the brain cells.

The acids are generally sour; the bases or alkalies, caustic. These change in combination with other bodies. The acid and alkaline taste can be produced by the electric current. If the positive pole be placed on the tip of the tongue and the negative on the nape of the neck a current will pass up the tongue from tip to root and will taste *sour.* But if the current is reversed by placing the negative pole at the end of the tongue and the positive on the neck, the taste is generally alkaline. Even weak currents produce the effect. If a piece of zinc plate be placed on the tongue and a piece of copper under it in such a way that the metals touch each other over the end of the tongue, a galvanic current will be generated and an alkaline taste will be perceived. If the metals be reversed—the copper above—the taste will be acid.

The sense of taste is probably the youngest of the specialized senses. The condition of its nerve connections would indicate this. The optic

auditory, and olfactory organs are supplied with heavy nerve trunks, proceeding from the brain, which are devoted exclusively to the work of their respective senses. The optic nerve has no branches till it reaches the retina. The olfactory divides into three branches, all of which enter the nose and are distributed on the pituitary membrane, the septum, and the outer walls of the nasal openings, respectively. Only the first of these divisions ministers to the actual function of smell, but in all probability they all did in the ancient history of the race, or its ancestors, and now represent a function, altered or decayed, through the

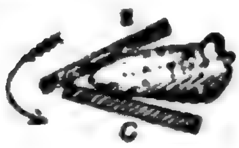


FIG. 229.

FIG. 229.—*Showing Current of Electricity* generated by placing the tongue between two plates, one of Copper and the other of Zinc. Current passes from the zinc to the copper.

changed habit of the race. The auditory nerve beginning in the medulla oblongate, has no branches till it reaches the ear, where it divides into two, one going into the cochlea and the other to the vestibule of the ear. But the nervous functions of the sense of taste appear to be divided between two nerves, neither of which constitute an independent and exclusive trunk. One of these is one of many sub-divisions of the glosso-pharyngeal (or 9th pair). This pair, besides sending some fibres to the papillæ on the posterior part of the tongue, also supplies the muscles of the pharynx and tongue, the mucous glands of the mouth, and sends numerous connections to other parts. The second taste nerve is one of fourteen branches of the trifacial, or 5th pair. Other branches of this nerve go to the eyelids, forehead, nose muscles, eye muscles, upper and lower teeth, upper lip and cheek, four muscles of the lower jaw, and to the shell of the ear. These comparatively uninfluential taste nerve connections, and the heterogeneous company in which they are found, lead to the suspicion that their adoption of their present functions, has been a comparatively recent event, most likely not dating back of the mammal tribes. In short, these are old afferent nerves of touch, the functions of which have become changed to afferents of taste without alternation of their anatomical position. In the mammal embryo, the nerves of taste do not correspond to an isolated part of the brain, as do the olfactory nerves (*Agassiz*). If, as before suggested, the fishes do their *tasting* chiefly through the nasal grooves and the olfactory lobes, it would follow that in the mammal families the fish organ of taste has been modified from a taste organ in the water to a smell organ in the air, and such modification, so necessary, obvious, and easy, has left its tracks in the remains of taste functions that still appertain to the sense of smell, as we have it. The tongue of fishes, in such case, might be anticipated to be destitute of a taste sense, and so, for the most part, it is. In general, their tongues are cartilaginous and often covered

with teeth. They swallow their food without mastication, and will swallow artificial bait readily enough if natural in appearance. In reptiles and amphibians too, the sense of taste seems to be confined to such semblance of it as may reside in the nostrils. Those of them that possess tongues that are extensible, like the snakes, toads, frogs and chameleons, use them as organs of touch, or weapons for striking and taking prey. The birds, inheriting from the reptiles, have probably not retrograded, but they show little or no advance in the sense of taste. The sense of smell in them is well developed, as an aerial sense. But their tongues are generally cartilaginous, and they often swallow their food without mastication. The tongue of the woodpecker is barbed at the point, and is simply a weapon for taking prey. Parrots have a fleshy tongue and are supposed to possess a better sense of taste than any others. (*Cuvier.*) This sense is greatly a creature of habit, and may become accustomed to the nicest discrimination of flavors, as in the case of wine tasters and tea drinkers, &c.

CHAPTER LI.

PHYSIOLOGY OF THE MUSCLES.

Contraction in a longitudinal direction results from the magnetization of certain conductors of yielding constitution. "Let discharges from a Leyden jar or battery be passed through a platinum wire too thick to be fused by the discharges and free from constraint, it will be found that the wire is shortened. It has undergone a molecular change, and apparently been acted on by a force transverse to its length. If the discharges be continued, it gradually gathers up in small irregular bends or convolutions. So with voltaic electricity. Place a platinum wire in a trough of porcelain so that when fused it shall retain its position as a wire, and then ignite it by a voltaic battery. As it reaches the point of fusion it will snap asunder, showing a contraction in length, and consequently a distension or increase in its transverse dimensions. Perform the same experiment with a lead wire, which can be more readily kept in a state of fusion, and follow it as it contracts by the terminal wires of the battery; it will be seen to gather up in nodules which press on each other like a string of beads of a soft material, which have been longitudinally compressed.[1]

Prof. Owen uses the following language:[2] Amber or steel, when magnetized, seem to exercise selection; they do not attract all substances alike. To the suitable ones, at a due distance, they tend to move, but through density of constitution cannot outstretch thereto; so they draw

[1] Correlation of Physical Forces, 95.

[2] Anat. of Vertebrates, Vol. 3, 818.

the attracted substance to themselves. If the amber be not rubbed, or the steel bar otherwise magnetized, they are "dead" to such power. The movement of a free body to a magnet has always excited interest, often wonder, from its analogy to the self motion so common and apparently peculiar to life. . . . A speck of protogenal jelly or of sarcode, if alive, shows analogous relations to certain substances, but the soft yielding tissue allows the part next the attractive matter to move thereto, and then by retraction, to draw such matter into the sarcodal mass, which overspreads, dissolves and assimilates it.

We say that the Protogenes, or Amœba, has extended a "pseudopod," has seized its prey, has drawn it in, swallowed and digested it. No "organs," however, are recognizable; neither muscle, mouth nor stomach. "If the portion of iron attracted by the magnet, became blended with the substance of its attractor, the analogy thereto of the act of the amœba would be perhaps, closer, more just than that other analogy which is expressed by terms borrowed from the procedure of higher organisms."

When protoplasm is subjected to the influence of a galvanic current, it contracts as a lead wire does; that is, the energy of the current disposes its atoms after that fashion. Not that the protoplasm does anything, any more than mud does when struck with a stone. It would be just as correct to say that mud *indents* when struck, as it is to say that protoplasm *contracts*, still there is no harm in using the term with the understanding and reservation here pointed out. Contractility, then, is a property of protoplasm, and we see it in action in the Amœba, the white blood corpuscle, and all the forms of the most simple protoplastic organization. Probably the very first differentiations are those which relate to this quality of contractility, and consist in the rendering of certain parts, through habit of use, more contractile than other parts. The Amœbæ push out and draw in first one part and then another, apparently with little or no choice of part, one being about as contractile as another. But in the Actinophrys and in the Foraminifera the parts used, the pseudopodia, are more or less constantly the same. They have acquired greater facility and are more rapid and more varied in their movements. Around the mouth of the Vorticelli, and other infusoria, there is a row of vibratile cilia. These consist of hair-like processes which, by their constant motion, create a current of water flowing into the mouth and carrying with it particles of matter. Such of these particles as are suitable food for the animal are absorbed and the rest rejected. Others of these low organisms, as, for example, the spores of the microscopical Algæ, &c., possess cilia on their outer surfaces by the vibrations of which they are caused to rotate in the water and to move about. Still others are furnished with one or more long

tails by the waving of which a progressive motion is accomplished; for example, the Monads and other Flagellata. None of these organisms have any visible nervous system. Even in the Corals, Sea-anemones, Dead-man's-toes, Sea-pens, &c., in which some of the cilia are developed and expanded into tentacles or waving arms of considerable size, no distinct nervous system appears to be differentiated. As we shall see further on, all muscle tissue is contractile and capable of receiving stimulus either by way of or independent of nervous agency. The nerves are differentiated fibres set off by habitual use to the conveyance of stimuli to parts of the organization remote from the point of habitual stimulation. Before such differentiation, therefore, the muscle—for example, a tentacle—itself performs the double office, and receiving the stimulus at one extremity or upon one side, after being affected by it, furnishes it conveyance to the other extremity or the other side, which in turn receives its contracting stimulus.

The most elementary organs of the nature of muscles in the vertebrate, as well as the invertebrate organism, are the vibratile cilia. These processes are found in various internal parts of Birds, Reptiles and Mammals. In Man they are found on the mucous membranes lining the nasal passages, the trachea and its branches, the uterus and its outlet, and the ventricles or cavities of the brain. Such a membrane is called ciliated epithelium, and it is constituted like other epithelium, with a submucous vascular layer at the bottom supplying nourishment to the layer of young spherical nucleated cells immediately above; above that a layer of mature nucleated cells squeezed into the shape of so many vertical cylinders standing side and side; on the top of each of which are several waving cilia. The whole calls to mind a colony of monads standing side by side waving their tails. Their vibrations are constant and

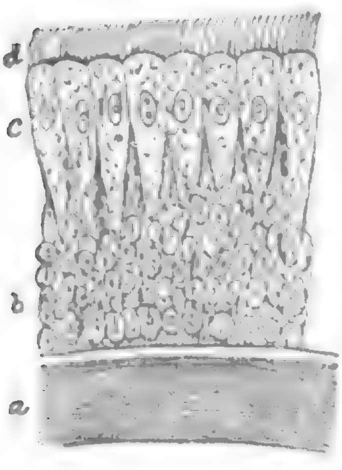


FIG. 230.

FIG. 230.—*Vertical Section of Ciliated Epithelium.*
a.—Sub-layer containing blood-vessels.
b.—Layer of the young newly formed epithelial cells.
c.—Mature cylindrical cells.
d.—Cilia on the free surface of the epithelium.
(The air passages of the nose and wind-pipe and cavities of the brain are lined with this sort of epithelium.)

are independent of the nervous system and beyond the control of the will. The movement is probably due to the conversion of friction or heat into electrical or nervous movement, by which the cilia are contracted alternately on opposite sides. The movement will sometimes continue after the epithelium holding the cilia is detached from the body. This automatic waving motion of the cilia has the effect of aiding the movement of mucus over the mucous membrane, and generally in the direction of the outlet to the organ in which it is placed. The palate of the

frog, however, is covered with ciliated epithelium, the cilia of which operate to work the food inwards towards the gullet. The evolution or differentiation of such organs as these minute self-acting muscles, antedates in animal history the differentiation of nerves and muscles proper. The evolution of muscles is a process which must have begun in the first animal whose body was big enough to admit of flexibility.

Amongst the lowest animals in which there is a definite nervous system, we find also well defined and correlated muscular action of parts. In the Medusa, or Jelly-fish, which is perhaps the lowest in which a clearly defined nervous system exists, the shape of the animal being like an umbrella, the simple ganglia are distributed all around the margin of the animal; and when a stimulus, as a touch, blow or stroke is applied to any part of this margin, it is instantly conveyed to every other part, and every muscle is thus stimulated to contraction at once, causing the closing of the umbrella, the expulsion of the water, and the backward rebound of the animal.

Vegetable protoplasm is contracted by electrical stimulus, and is differentiated in some cases to contraction from *nervous* stimulation generated in the tissues of the plant. (See chap. 54.) It has never been settled precisely what the nature of the nervous current is. But it seems to be generally supposed to be something akin to a galvanic current. There are many ways in which the movement of ether makes itself apparent; and these different modes appear to depend upon the conditions under which the movement takes place, just as the force of a head of water may show itself in an unconfined rush over a dam, or may propel an undershot wheel, an overshot wheel, a turbine or a hydraulic ram, all exhibiting different forms of movement, arising from the same source. The ether, like the water, when descending from a position of potential energy, may do so through various mediums, and so exhibit itself in various forms. Again, there are waves of different sizes possible in the same fluid, as water for example. The wave produced by dropping in a shot is greatly different from that produced by the tumbling of an iceberg; and the motions possible in a bucket of water but little resemble those produced in the sea. So we find that the waves set up in ether are of different sorts and lengths, depending upon the nature of the body from which they originate. The waves excited by a tallow candle differ from those of the arc light. So there is a great difference in ethereal currents. The electric spark, the direct galvanic current, the galvanic induction current, the magnetic current, the thermo-electric current, all differ in their origin, and more or less in their manifestations, but are nevertheless of the same family. There is ample reason to assign a place in the same list to *nervous energy*. The intimate nature of the difference between the various forms of ethereal en-

ergy, when current, can only be conjectured. The term current itself is used in a rather vague way in this connection, and is applied indifferently to the movement in all sorts of nerves, as it is to the movement through metallic conductors; when the fact may be that the movement up one nerve may be by a progression of vibrations, like those of light, while up another it may consist of a succession of pulsations, like those of sound. It may even consist of a rush of the ether itself along the conductor. If it should turn out to be either a succession of pulses or a succession of undulations, we can readily comprehend how it might occur in different tones or wave-lengths, and how, like sound, light and heat, it is retarded in its passage through its conductors; and how it gets through some of its nervous conductors more rapidly than through others. The nerve current cannot be propagated over a nerve that has been divided by a transverse cut, even when the ends are placed in as close contact as possible, while magnetism will traverse such a break. A divided nerve connected by a piece of wire, will convey a current of electricity but not a nervous current. Moreover, the neurilemma, or enveloping sheath of the nerve fibres, is a non-conductor of nervous energy and serves to insulate the fibres as against that, while it is a conductor of electricity. At the same time, however, nervous energy is interchangeable with the other forms of polar and molecular energy.

The connection between nerves and muscles is extremely intimate, and what is called the power of contractility of the muscles is never brought into exercise in the body except upon a stimulation by a nerve current. The nerves are divided into two general classes. Those which convey stimulations from the organs of sense to the general nervous centers, viz., the *spinal cord and brain*, are called *afferent* or *sensory nerves;* while those which convey stimulations from these centers to the muscles, causing their contraction, are called *efferent* or *motor* nerves. Sometimes the former are called *centripetal*, and the latter *peripheral* nerves.

Assuming that nervous energy is a form of polar energy of which electricity is the type, I shall speak of it as electricity and current, because there are no more convenient terms. To this form of energy, then, is every other form reduced before it can have any effect upon an organism through its natural organs. The change is always from a mode of motion external to the body, to a mode of motion internal. The external motion, called light, agitates the rods and cones of the retina, and is reduced by them to the nervous current of the optic nerve. Those called heat, touch, and pressure, agitate the epithelial and tactile cells, and are reduced by them to the nervous current of the skin nerves and epithelial nerves. Those vibrations called sound agitate the auditory organs and are changed by them to the nervous current

of the auditory nerve. These currents all tend to a common center in the spinal cord and brain, and are returned thence along the efferent nerves to the muscles, stimulating them to contraction. The greater part of the energy of the nervous current is consumed in the work of muscular contraction—that is, disappearing as nervous energy it reappears as work, and so passes on out of the system back into the environment, which furnished it in the first place.

It will be seen also that tetanus of a muscle, or a continuous strain of the fibres, causes them to give off an electrical current. Such action is also accompanied by heat. The physiological change in the muscle when contracted consists in the elimination from its tissue of some of the elements, especially some of the carbon composing it, and its union with oxygen contained in the blood, forming thereby carbonic acid, which is carried off through the lungs. A part of the heat liberated in the destruction of the muscle tissue is immediately turned into electricity, and may be conveyed as such by proper appliances and stored in a Leyden jar. All muscular action produces heat and without doubt electricity, too.

The number of muscles in the human body is variously reckoned as low as 368 and as high as 400. The greater number are in pairs. A few are azygos[1], as the heart, diaphragm, several of the sphincters[2], &c. They are of various shapes: long, broad and short. They are said to be *Simple* when the fibres all run parallel with each other in one body or "belly," as [3]sartorius, [4]pronator-quadratus, &c; *Compound*, when with one body they are connected with their attachment or insertion by two or more tendons, or when there are several connected bellies and several tendons, as [5]*biceps-flexor-cubiti*, [6]*sacro-lumbalis*, &c.; *Radiated*, when the fibres diverge from a common center like rays, as the [7]diaphragm, [8]iliacus, [9]temporal, &c; *Pennated* or *Pinniform*, when their fibres are arranged in two rows which are united to a tendon in a median line, at an angle, like the feather fibres of a quill to its central stem; as the [10]*palmaris-longus*; *Semi-penniform*, when the fibres are oblique but joined on one side of the tendon only, like one-half of a split quill. Hollow muscles are such as the heart, intestines, urinary bladder, &c. They are likewise distinguished as *voluntary*, and striped or *striated*, and *involuntary smooth* muscles. The former are those which ordinarily are, or may come under control of

[1] Un-yoked, hence not paired.
[2] Muscles in the form of a ring for closing an orifice like the mouth, &c.
[3] Tailors' muscle, used in raising the leg to cross it.
[4] In the fore-arm. It rolls the fore-arm and hand inwards.
[5] Bends the fore-arm upon the arm.
[6] In lower part of the back; straightens the backbone backward.
[7] Partition across the body cavity.
[8] Connects lower part of the trunk with upper part of thigh; holds the trunk from falling backward.
[9] On side of head; raises lower jaw.
[10] A long muscle in the arm for bending the hand.

the will. The *Smooth muscles* consist of elongated, band-like fibres free from striation. In the intestines which are moved by smooth muscles, some of the fibres are longitudinal and others transverse or ring-like. The fibres of the *striated* muscles are arranged in bundles or fasciculi, which are enveloped in and bound together by areolar or connective tissue, which also supports the nerves and vessels of the muscles.

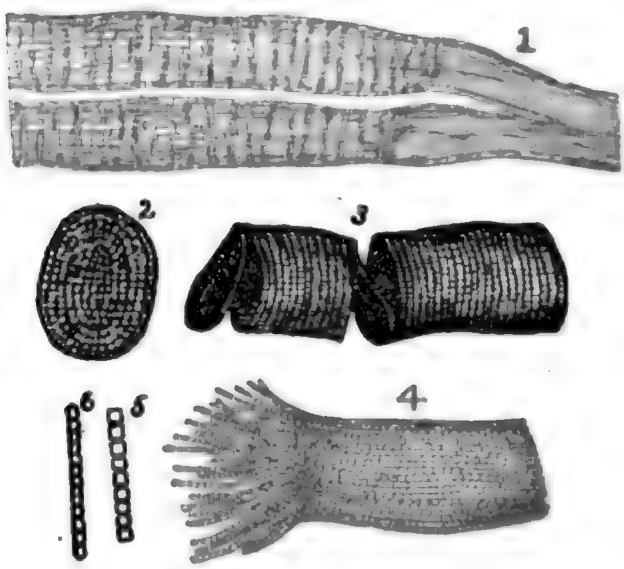


FIG. 231.

FIG. 231.—*Striated Muscle Fibres.*
1.—Two fibres cut off at the left and running into tendons at the right.
2.—Cross section of a fibre, showing ends of fibrillæ and areolar connective tissue.
3.—Fibre pulled apart forming discs.
4.—Fibre split up into its fibrillæ at one end.
5, 6.—Single fibrillæ.
There are about 625 fibrillæ in a fibre.

Each fibre of the bundle above described is enveloped in a sheath called the sarcolemma. This is a membrane, transparent and very delicate, but tough and elastic, and it separates the fibres from each other and from all other tissues. It is not penetrated by nerves or blood vessels. On account of the pressure of the fibres upon each other their shape is polygonal rather than round or cylindrical. They will average in diameter about $\frac{1}{400}$ of an inch. Each fibre is susceptible to a still further subdivision into minute threads called *fibrillæ* or fibrils. Each of these fibrils is composed of a series of dark-colored cells, each cell surrounded and enclosed by a pellucid border, the effect being to give the fibril the appearance of a string of dark-colored beads separated by light-colored partitions. These light-colored partitions in any one fibril come directly opposite those in the other fibrils, which circumstance gives the appearance of the transverse striæ across the fibre above spoken of. If a fibre be pulled apart by a longitudinal strain it is apt to divide in these transverse markings, and so separate into discs or plates, each disc composed of one cell from each fibril. (Fig. 231.) When the muscle is relaxed, the beads or cells which constitute the fibrils are elongated; their longitudinal diameter being greater than the transverse. But when it is contracted, the fibril cells are squeezed together endwise and the transverse diameter becomes greater. Each of the ultimate strands or fibrils, therefore, acts under stimulus in a manner which closely imitates the behavior of the melted metallic conductors spoken of above. The cells which compose the fibrils are therefore polarized units, which, by their mutual polar attractions shorten, and consequently widen when under stimulus, the united action causing the general shortening and widening of the whole muscle. This also corresponds with the contraction of certain vegetable

tissues, whose movement is known to be caused by a like alteration of the shape of their ultimate cells under stimulus. The fibres are not to be supposed thrown into zigzag lines since fibres in this state cannot be supposed to exercise any force of traction. The very nature of the strain would tend to straighten the elements if crooked. (*Neil & Smith's Physiology.*)

The blood vessels that supply the nourishment to the muscles, ramify in the shape of delicate capillaries in the spaces between the fibres, but do not themselves penetrate the sarcolemma, the nutrient matter being absorbed by the cells through the membrane of the sarcolemma and their cell walls, and the waste discharged by the converse process. The motor nerves also penetrate the areolar tissue between the fibres, and discharge their stimulus through that coat in a manner explained further on. Once inside the sheath the stimulus is propagated along the cells without again leaving the fibre, the sheath forming a sufficient insulator. When a muscle fibre is stimulated at any point, it begins to contract at that point, and a wave of contraction passes along the fibre at the rate of from ten to thirteen feet per second. The pulsating vibrations which produce tetanus, do not have any effect if they exceed about 800 to the second, as the ultra violet waves do not affect the eye.

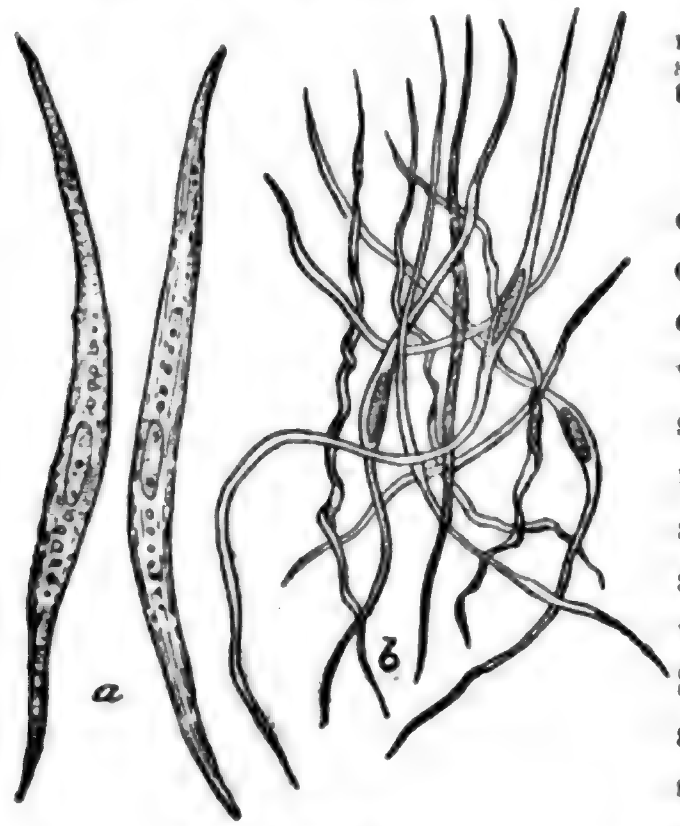


FIG. 232.

FIG. 232.—*a, Smooth-Muscle fibres.* Magnified 300 diameters. They are elongated, spindle-shaped cells, having a nucleus near the middle.
Some are spirally twisted (*b*).

In the smooth muscle, the fibres consist of a series of tubes which do not show any transverse marks or striæ. They cannot be subdivided into fibrils. They are smaller than the fibres of the voluntary muscles, and at intervals along them there are nodules which are the nuclei of the cells from which they were originally derived. Some have pointed ends, which are sometimes twisted like a cork screw; and they have elongated nuclei. They are destitute of the insulating sheath, or sarcolemma. They do not form separate masses but occur scattered or arranged in more or less dense layers, or strata, in almost all organs. These muscles are stimulated in their natural action by the direct contact and friction of substances, such as food (in the intestines), blood (in the arteries), &c., and are but little under the influence of the central nervous system. The peristaltic action of the

alimentary canal, including the throat, stomach and intestines, and the urinary duct, consists in the contraction of the transverse fibres, or those which run around the tube of the intestines, or other canal; such contraction beginning in the upper end, and being followed successively by the contraction of the fibres below; the effect being to drive the contents of the organ before the slowly moving wave of contraction. At the same time the longitudinal muscle fibres, by their contraction, tend to pull up the tube over its contents, which are carried down with it as the contraction relaxes. Smooth muscle constitutes the walls of blood vessels, some of the fibres running parallel with the tube, and others around, as in the case of the alimentary canal; their contractions which, in the case of arteries, appear to be controlled by some sort of automatic machinery (perhaps internal pressure of contents), tend to diminish the size of the tube and retard the flow of blood into the capillaries.

When smooth muscle is irritated by electricity, the stimulus spreads across from one fibre to another, showing no insulation of fibres, but when the striated fibre is stimulated in the same way, the stimulus with accompanying contraction confines itself to the fibres receiving the charge, unless the irritation is very strong, showing the sarcolemma to be to a certain extent an insulator.

The heart is an involuntary organ, but is peculiar in being composed of striated muscles which, however, are destitute of sarcolemma, so that an irritation applied to any part of the organ is spread over and excites the rest. Another peculiarity is in the fact that the heart muscle fibres are branched, in which oddity it imitates the muscles of the tongue of the frog, which are also branched like a tree. [1] Striated muscles occur in the intestines of the Tench, a fresh-water fish of the carp family. Du Bois-Raymond is the highest authority on the muscles and his experiments are the oftenest quoted. Experiments with muscles detached from the body are commonly made with those of the frog, generally the gastrocnemius or calf muscle of the leg. The frog being cold blooded his muscles can be kept in the normal state longer than those of a warm blooded animal.

The muscles of mammals detached from the body lose their power of contraction in from 20 to 30 minutes. The muscles of frogs, however, retain their contractile power in some cases as long as forty-eight hours in an ordinary temperature. At a temperature of 0° to 1° C (near freezing point) the same muscle might retain its contractility for eight days. At a temperature of 45° C, 113° F, however, the contractile power is lost in a few minutes. (*Rosenthal.*) Fresh muscle from the frog does not shorten spontaneously, but will contract when irritated, as act by pinching with tweezers, or smearing with strong acid, or by electricle. 1 &c. These are called irritants.

thal Muscles & Nerves, 101.

Electric shocks are best applied by induction. (See fig. 144. The coil *b* is placed inside of *c* and then the circuit through *b* and the battery *a* is arranged to be opened and closed readily with a key.) The sudden interruption (unclosing) of the current through the active coil *b*, produces an instantaneous shock through the silent coil *c* and a sudden contraction of the muscle attached to it, another shock and another sudden contraction occurs when the current in the coil *b* is again closed. A direct current from the battery itself is also capable of acting as an irritant on muscle, a pulsation generally occurring when the current is interrupted, and again when it is closed or connected. If the current remains closed, the muscle after the first contraction will partially relax and remain so during the passage of the current. But by placing a small ratchet wheel in the line of the current by the turning of which with a crank the operator can rapidly break and connect the current, the irritations can be repeated more rapidly than the muscle can recover from the shocks, so that permanent rigid contraction or *tetanus* is produced. Muscular action, therefore, is in the form of a sudden pulsation, or the enduring *tetanus*; which is really a succession of pulsations without sensible interval. Every muscle is capable of accomplishing a certain amount of work by contraction. The following table shows what was accomplished by a particular detached muscle before its contractility was exhausted. The muscle was suspended and weights attached to it.

Weight applied, in grammes	0	50	100	150	200	250
Hight raised, in millimetres.....	14	9	7	5	2	0
Work done = so many grammes raised 1 m. m.	0	450	700	750	400	0

In this particular case the best results came from the work expended on 150 grammes. The *thicker* the muscle the greater the weight it can raise; the *longer* the muscle fibres the *higher* the weight can be raised.

In the foregoing experiment the muscle action was upon pulsation, not tetanus. The work done in tetanus is in first raising the weight and afterwards holding it up. The labor of raising the weight under the stimulus of a single pulsation as above is accompanied by heat or molecular change in the ultimate molecules of the muscle, which change is not noticed in the table and would not be easy to estimate. It is one of the forms of energy exhibited in the movement of the muscle, the other demonstration of energy being the visible contraction and lifting of the weight, which alone is shown in the table. In tetanus when after the weight is lifted, it continues to be held up by the continued irritation of the muscle, the amount of heat disengaged is greatly increased; the appreciable sign of the work done in the holding up being the increased molecular vibrations in the muscle itself, indicated by the sen-

sible heat. It is abundantly obvious in this case that the galvanic battery which furnishes the irritations, is a substitute for the central ganglions of the nervous system; viz., the spinal cord and brain. In life the striated muscle contracts only when stimulated from these centers, and the nature of the stimulation is by these experiments clearly indicated. When a tetanus or continuous contraction of the muscle occurs, it is the result of a continuous series of rythmically interrupted pulsations of the nervous current. The experiments show that a single pulsation of the current results in a single contraction of the muscle, followed by its relaxation; while, if the current is continuous and uninterrupted, the contraction takes place suddenly when the current first begins, which contraction is followed by relaxation not quite complete, leaving the muscle in a state of partial contraction which continues while the current passes.

Accompanying the molecular motion of a tetanized muscle is a *musical sound.* This varies in pitch with the rapidity of the irritations or pulsations of the muscle, which depends on the rapidity with which the ratchet is turned and the current interrupted. The pitch heard during *voluntary* contraction of the muscles is C′ or D′, equal to 32 to 36 vibrations per second. Helmholtz thinks this is the first harmonic of the real tone, which he supposes to be an octave lower, but which is inaudible to the human ear. When the motor nerve trunk, or spinal cord, of an animal is irritated by chemical means, the muscle sound has been found due to 19.5 vibrations. The pitch heard during voluntary contraction obviously indicates the number of pulsations or *waves of ether* per second sent from the brain to the muscle. When the muscle is contracted by the artificial irritations of an interrupted galvanic current, the sound corresponds to the pitch due to the number of interruptions per second, and may be made to run up as high as 800 to 1,000. The result is the same whether the irritation is applied to the muscle direct or to its nerve, except that in the latter case the sound is not so loud. The sound is due to rapid molecular changes taking place in the molecules of the muscle—changes in the *density* of the muscle, according to Landois and Stirling.

When the muscle is caused to contract by an irritation delivered from a nerve, it is apparent that the force of the muscle contraction is very much greater than that of the nerve current which starts it. It must be, then, that the nervous force, when it irritates a muscle, unlocks and liberates an energy much greater than its own. The energy of the body, like that of a steam engine, is derived chiefly from the combustion of carbon. This combustion takes place in all parts of the body, and it consists, as before stated, in the union of oxygen with the different tissues of the body, especially the muscles and nerves. The oxy-

gen is conveyed to all parts of the system by the blood, especially by the red corpuscles. And wherever it is, it must be in close contact with the oxidizable tissues. But for some reason these two elements, viz., the oxygen of the blood and the carbon of the tissues, appear to be unable to unite, hungry as they may be supposed to be for each other. But this union can take place only on conditions. Carbon, in some forms, is very slow to unite with oxygen. As charcoal, it may be exposed to oxygen a long time without change. Oxygen itself, as we have seen, may be met with in very different conditions. As ozone, its intensity and force are very greatly increased, and in that state it is competent to form unions which it cannot form in its ordinary state. But an electric current, even a feeble one, is competent to rearrange the molecules of oxygen into molecules of ozone. According to Draper, that is what takes place. Wherever the nervous current is sent, the oxygen in the blood in reach of such current becomes ozone, and then, by virtue of its more intense combining power, it at once combines with some of the constituents of muscle, developing heat and electricity. It can scarcely be doubted that the muscle contraction which follows is due chiefly, if not entirely, to the sudden magnetization of the muscle by the electricity thus generated. No doubt the sudden abstraction of the many molecules of the muscle tissue which then takes place, contributes to the facility and extent of the contraction by enlarging the molecular spaces in the muscle; but the efficient *cause* of the contraction is the energy of the contractile electric or magnetic tensions established in the muscle. These tensions are exhausted and abolished each time the muscle contracts, and renewed each time a pulsation or wave of the current is shot down the nerve from the brain or spinal cord.

Physiologists are not agreed as to the detail of the causes of muscle contraction, or of the production of ozone in the blood. Antozone as well as ozone is produced, and it certainly cuts an important figure in the chemical reactions which take place. (Landois.) All the reactions produce heat and electricity, even when the body is at rest. The movement of the blood even in sleep does this. And it is not improbable that there is a partial storage of electricity in the muscle fibres accumulating during the process of repair which goes on during periods of resting. This happens in the case of the electric fishes, and the liberation of this stored energy is made, in their case, by the voluntary discharges down the motor nerves from the brain. If there is such a storage in the case of the voluntary muscles, it is obvious that the current from the brain down the nerves operates in some analogous way to discharge the tensions, and permit their conversion into muscle contraction.

The *nerve* tension is generated in precisely the same way in which the muscle tension is generated; but its tension may become exhausted in

a current instead of a contraction. As an illustration let us see how a boy dodges a snow-ball. First, he sees the ball coming. This means that the *light* reflected from the ball, decomposes some of the tissues of his retina and produces electric tension there, which sends a current to the brain. Dewar has demonstrated that light falling upon the eye has this effect of setting up an electric current in the optic nerve. There is in the brain the same state of things that is found in the muscle. The brain is permeated by fine blood vessels holding oxygen, waiting to be united to the tissue composing the brain. The current from the eye up the optic nerve, furnishes the necessary force to enable this union to take place. And this union, as in the case of the muscle, develops electrical tension, which instantly relieves itself in a current to certain muscles. Here a new tension is created, followed by contraction, which quickly throws the body or head of the boy to one side, and the ball is dodged.

The average force of the muscle contractions is probably from six to ten times as powerful as the force of the nerve currents which set them off. It is ascertained that about one-fifth of the blood of the body goes to supply the brain. A considerable part of this is consumed in the production of brain changes which do not result in movement of muscles, but in thought, emotion, &c. The other four-fifths supplies the work of digestion, secretion and muscle contraction. The lifting power of the muscle of the fore-arm in man, is at the rate of about 100 pounds per square inch cross section of muscle fibre. For the muscles of the feet, calf, &c., the power is considerably less. Of course the contractions of the muscle are made at the expense of its own tissues, some of them being used to create the electricity by which the contraction is produced.

A muscle out of the body will recover from exhaustion partly, but not completely, of course. Each stimulation uses up the power of recovery till it is soon lost. In the living body, however, this power of recovery is continuous while nourishment is supplied to the muscle in the blood, till it diminishes by the wearing out of the system in age or disease. During health, exhaustion and recovery of muscle adds to its power, so that it may *recover more than it loses.* (*Rosenthal 80.*) It is in consequence of this extremely important fact that *exercise* of any part strengthens and adds to it. There are many cases in which bodies enter into combination with other bodies with much more energy at the instant they are disengaged from former combinations. At this instant they are said to be in a *nascent* state, that is, just born. Exercise, by reducing some of the constituents to this fresh condition, allows of this more complete recombination, and hence an improved condition.

The muscle fibre terminates at each end by a perfect disc, which is

connected with a fibre of tendon tissue. The tendons connect the muscle with the bones, or other part to be moved. The attachments of the muscles to the parts to be moved, are generally such that power is sacrificed to speed of movement. Thus the biceps muscle of the arm, which is attached at its upper end, by two prongs, to the shoulder blade, and runs down the humerus, is connected with the radius bone of the fore-arm only about an inch and a half from the joint. (See fig. 86.) So that a contraction of the muscle amounting to an inch, will move the hand about ten times as far, with a loss of nine-tenths of the power. The biceps of the thigh is arranged in an analogous manner.

There are arrangements in some cases which add to the power of muscles. Thus the patella, or knee pan, is a projecting bone to which the extensor muscles are attached and which add to their power by adding to their leverage in the straightening of the leg. In the case of the superior oblique muscle of the eye, the muscle is carried through a cartilaginous pully which is attached to the frontal bone, and is doubled back on itself, so that when it contracts, its point of insertion on the globe of the eye is moved in a direction contrary to the direction of the contraction. The muscles in their natural attachments are in a state of tension so that if one were cut in two it would shrink in length. Muscles on opposite sides of a limb, as the flexors on the inside of the leg and the extensors on the outside, have a tendency to draw the bones together in their sockets. When one of these is contracted its opposite is stretched.

A muscle being a generator of electricity, it may be made a part of a circuit, and when out of the circuit shows the positive and negative tensions which are to be observed in the metallic battery. A muscle prism is a bundle of straight parallel fibres cut off square at both ends. The

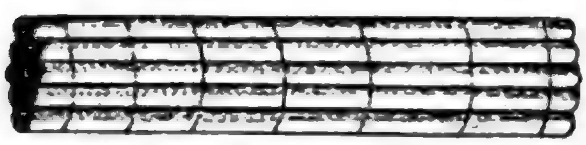


Fig. 233.

Fig. 233.—*A bundle of muscle fibres forming a regular Muscle Prism.*

surface of this which exposes the sides of the fibres is called the longitudinal section of the prism, while that which shows their ends is the cross-section. An imaginary line passing around the prism across the fibres and dividing the prism into two symmetrical halves is called the equator, because at every point on such a line a higher positive tension prevails than is to be found on either side of it.

Every point on the equator has a greater positive tension than any other point on the longitudinal section or the cross-section. The positive tension decreases along the longitudinal section each way from the equator, until at the point where the longitudinal meets the cross-section,

where it is 0. The tension is negative all over the cross-sections, and is greatest in the center of these, decreasing from these centers to the edges where the cross-section meets the longitudinal section where it is 0 [1].

When the shape of the piece of muscle operated with is different, the tensions are differently distributed. In a rhombus the greatest positive

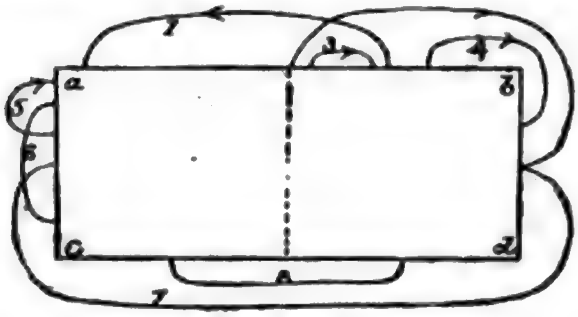


FIG. 234.—Diagram showing the principle on which current circuits are formed in a regular muscle prism. The arrow heads show the direction taken by the current. The tensions are equal at each end of lines 6, 7 and 8, so that there is no current in them. (*Rosenthal.*)

FIG. 234.

tension is moved nearer the obtuse angle on the long side, and the negative nearer the acute angle on the end section. In the calf muscle the tensions become more complicated. The large end is strongly positive and the small end strongly negative. (See fig. 235.) The current of greatest strength in this muscle is very strong. The action of oxidation of muscle which takes place suddenly when the muscle is irritated, takes place slowly when it is inactive, which accounts for the currents and tensions always found in it. But if during the passage of a current

FIG. 235.—*A Gastrocnemius or calf muscle of the leg of a frog* showing the direction of the magnetic currents in it when detached from the body. Its irregular *shape* causes the tensions to be different at almost all points.

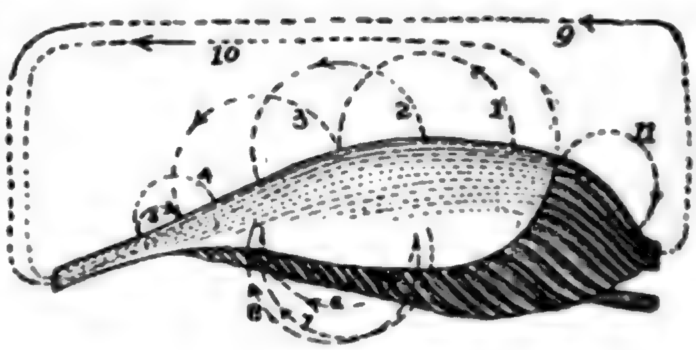


FIG. 235.

generated in the quiescent muscle, the muscle is made to contract, the current is weakened. This indicates that the current and the contraction have a common source of power, so that when one form of movement is in activity there is less power for the other. When the body is quiescent, the currents generated in the tissues on opposite sides of the body, neutralize each other on account of its bilateral symmetry. But if one side is active, electricity is evolved in greater amount. This was demonstrated by Du Bois-Raymond, who formed a circuit composed of his body and a galvanometer, the wires leading from the galvanometer terminating in two cups filled with salt water, in each of which he inserted a forefinger, thus completing the circuit. A sudden contraction of the muscles of the right hand and arm sent a current away from that side toward the left. When the left side was contracted the current was reversed.

The muscles of all animals, so far as examined, when quiescent, gen-

[1] The absolute 0 potential is that of the earth; but any point on the prism to which a current can be made to flow from other points is relatively 0.

erate electricity, and presumably a much greater quantity when active. Even smooth muscles act electrically the same way, but weaker, since by reason of the absence of the sarcolemma and the irregularity of the distribution of the fibres, the influence is scattered and dissipated.

The electric action continues for awhile feebly after the partial death of the muscle; that is, after the cessation of its contractile power, and ceases entirely upon death stiffening. The nerves which set up action in the muscles are called motor nerves, and they are directly connected with the inner or anterior part of the spinal cord, called the anterior horns or columns. It is shown that if these columns be destroyed or disabled, or the connecting nerves be severed, the nerves first undergo degeneration and lose their excitability, and after a time the muscles also lose their contractility and degenerate into mere connective tissue. This happens in acute or chronic *anterior polio-myelitis.* (Ferrier.) Mere disuse of the muscles while remaining attached to the spinal cord does not produce so sweeping a degeneration.

The muscles, or at least their membranous covers, are furnished with a net-work of non-medullated nerves which connect the muscles with the *posterior or sensory* horns or columns of the spinal cord. These are entirely independent of the motor nerves, and are evidently nerves of sense. No doubt they are the nerves of the muscular sense, and convey to the brain sensations of the exhaustion or fatigue of the muscle or stimulations of pressure, cramp or electrical irritations. The muscle is therefore a sensory organ for these sensations, as the skin is for heat and cold. The muscle sheltered under the skin has lost, while the exposed skin has retained, the sensibility to heat and cold.

CHAPTER LII.

PHYSIOLOGY OF NERVES AND NERVE-CELLS.

The finest nerve fibre is extremely small; scarcely visible to the naked eye. It consists, when all parts are present, of a core or axis, which is usually flat and band-like, and a shell called the medullary sheath or marrow sheath. These two are further enclosed in another covering called the neurilemma or nerve coat. The axis, when seen under a high magnifying power, appears striated longitudinally, as if composed of still finer fibrillæ. The medullary sheath has a crumpled or wrinkled appearance, as if it were too big, and it contains a fluid which oozes out of a cut end of it and coagulates. The brain, medulla oblongata, and spinal cord, constitute the general centers of the nervous system. These centers are made up of nerve fibres and other bodies called nerve cells. *Ganglia* are masses of nerve cells. Nerve fibres, which connect the

brain with the extremities of the body, are called the peripheric nerves. All the peripheric nerves do not possess all the parts described above. Some have no medullary sheath, and consist, therefore, of axis cylinders immediately surrounded by the nerve sheath or neurilemma. When many nerve fibres are united into a bundle, these marrowless fibres are gray and more transparent, and are therefore sometimes called gray nerve fibres. Those nerve fibres which have medullary sheaths, appear more yellowish white.

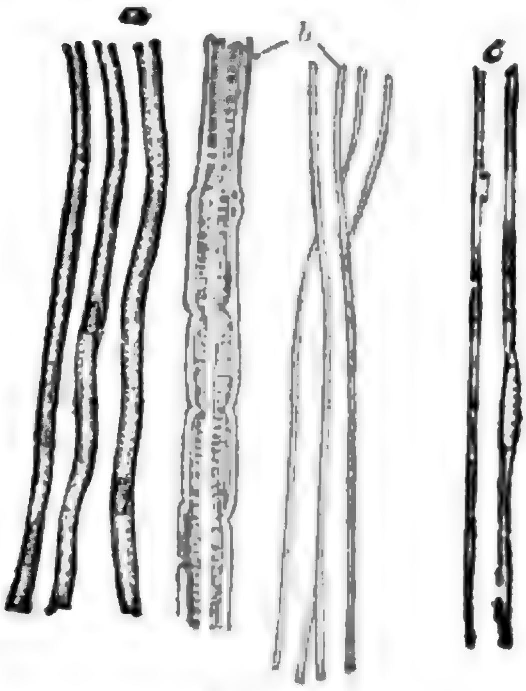


FIG. 236.

FIG. 236.—*Nerve fibres.* (*Shultze & Claus.*)
a.—Non-Medullated Sympathetic Fibre.
b.—Medullated Fibres, one of which has commenced coagulation of the axis cylinder (death of nerve).
c.—Medullated nerve fibre with the sheath of Schwann.

If the nerves are traced to the periphery, more and more nerve fibres are continually found to branch off from the common stem, so that the branches and branchlets gradually become thinner. At last, only separate fibres are to be seen, these being, however, still in appearance exactly like those constituting the main stem. Such fibres, as up to this point have had medullary sheaths, now frequently lose them, and therefore become exactly like gray fibres. The axis cylinder, or band itself, then sometimes separates into smaller parts, so that a nerve fibre, thin as it is, ramifies over a very large surface. The ends of the nerve fibres are connected at their outer extremity sometimes with muscles and sometimes with glands, which they excite to action. Such nerves are called motor nerves. Others are connected at their outer ends with the sense organs—eye, ear, tongue, &c., and these are called sensory nerves. At their inner ends they are connected with nerve-cells, *from* which, if they are motor nerves, they receive their stimulation, and *to* which, if they are sensory nerves, they carry it. There are vast numbers of short nerve fibres which connect the nerve cells with each other in the brain, spinal cord and ganglions, or cell-knots, in different parts of the body. The nerves in the brain and spinal cord are in the same variety of conditions as the peripheral nerves, being possessed of all the parts or destitute of some one of them. Each ganglion cell is composed of the cell body, the kernel or nucleus and the nucleolus. Some ganglion cells are surrounded also by a membrane, which is a continuation of the neurilemma of the nerve fibres that are connected with the cell. "The kernel is finely granulated, and is composed of a protoplasmic mass," which, in its normal state, is nearly transparent. Some of the ganglion

cells have processes or branches of the same matter as the cell; that is, finely granulated protoplasm. These processes become finer as they go from the cells, and branch out into several parts, and the parts from neighboring cells mingle with each other and connect the different cells

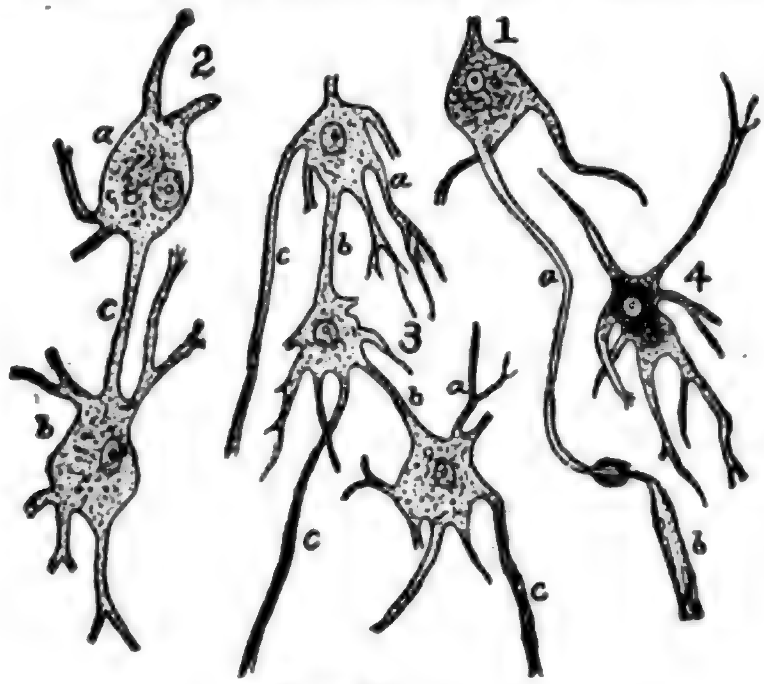


FIG. 237.

FIG. 237.—*Ganglion cells from Human Brain.* (*Rosenthal.*)
1.—A ganglion cell of which one process (a) becomes the axis cylinder of a nerve fibre (b).
2.—Two cells, a and b, interconnected.
3.—Diagrammatic representation of three connected cells, each of which passes into a nerve fibre. 4.—Ganglion cell partly filled with pigment.

together. But from each cell one or more fibres are sent out, which, at a little distance from the cell, becomes encased in a medullary sheath, and thenceforth becomes, in appearance and probably in fact, a

FIG. 238.—*Nerve Cells.*
a.—*Bipolar Ganglion Cell.*
b.—*Nerve cell* from anterior horn of human *Spinal Cord.*
p.—Pigment body. (*Gerlach.*)

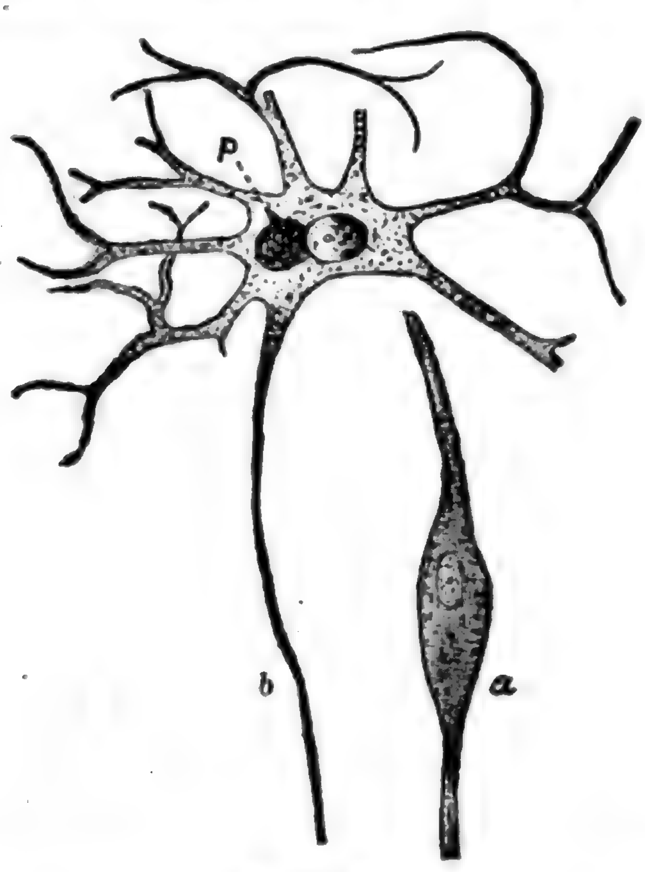


FIG. 238.

peripheral nerve fibre, or a conductor to another cell. The peripheral nerves are simply conductors of the nerve electric fluid or movement. The central system is the medium of all motion and sensation. If one of the nerves connecting the central system, and a muscle be irritated, it will cause pain and also a contraction of the connected muscle. If the nerve is *cut* above the point at which it is irritated, the muscle below will still contract upon the irritation of the nerve, but the sensation of the pain will be gone. But if the nerve is cut *below* the point of irritation aforesaid, the pain

will be felt, but the muscular contraction or pulsation will not take place. Under the strongest irritation of a peripheral nerve it is impossible with the strongest microscope to discover the nature of the change that takes place in it, although, since the irritation passes through the nerve and irritates the muscle, it stands to reason that a change does take place in the nerve. If the calf muscle of the frog, with the sciatic nerve connecting to it, be used for experiment, the pulsation of the muscle may be produced by the irritation of the nerve mechanically, by pressure or constriction with a thread, or by cutting it; or chemically, by putting upon it alkaline matter or an acid, or it may be irritated by heating, another sort of mechanical irritant; or it may be irritated by electricity. All the chemical and mechanical irritations are abnormal, and soon destructive of the irritability of the nerve at the point irritated. But the electrical stimulus may be applied repeatedly without immediately destroying the irritability of the nerve. "It therefore appears that in this respect a nerve acts exactly as does a muscle." That is, it wears better under an electrical stimulus than under any other sort, showing it to be adapted best to that sort of stimulation, and by implication, therefore, to have been built up by that sort of a stimulation rather than by physical or mechanical jars. In experimenting with the *cortex*[1] *of the cerebrum*, no sort of mechanical irritation was ever found to have any effect whatever. It might be subjected to chemical stimulation, it might be heated or cut or pinched without exciting either sensation or motion. But the introduction, by Fritsch and Hitzig in 1870, of the galvanic current into their studies of the cerebrum, at once led to the unlocking of its secrets. The galvanic pile in the hands of the physiologist, takes the place of the normal will of the individual owning the brain. The electrodes, or poles, applied to different parts of the exposed cortex, cause the movement of the different muscles with which the brain is in connection.

A single inductive shock through a nerve produces a single pulsation in the muscle, and if a continuous series of shocks is applied, the result is tetanus in the muscle. The irritation of the nerve must be made at some distance from the muscle. If the nerve be cut, the effects cease and it cannot be mended by placing the parts in juxta-position, however well done, and although the nerve may appear to be uninjured, it wont work. If a thread is drawn tightly around the nerve it spoils it. After the thread is removed the crushed spot is an impassable barrier to the electrical stimulus. But the stimulus may be applied below the injured spot and the effects will be complete again.

It is proved by experiment on the nerves of frogs that the stimulation passes along the nerve, so that the longer the nerve the longer it takes

[1] The *bark* or outside surface of the brain.

to convey a stimulus to a muscle. Helmholtz found the speed of the propagation of nervous stimulation to be about 78 feet per second. It is not quite constant, being greater in higher and less in lower temperatures. It is possible to agitate the human nerves *through* the skin, especially when they are situated near the surface, since the skin is a fair conductor. Helmholtz' experiments on the live human nerve showed a speed of about 97 feet per second, the higher rate accounted for by the higher temperature of the warm blooded over the cold blooded animal. This is the *average* speed of the propagation of the stimulus. But it is shown that the progress of the stimulus at first rapid, is gradually retarded, going slower toward the last; a fact due to the resistance of the conductor. If the main stem of a nerve is irritated by electric shocks, all the fibres composing it, and into which it branches, partake of the shock, but the insulation of the fibres is such that an irritation, however, made in a separate fibre, is not communicated to the other, and will excite only its own tract of muscle. The value of the insulation of a conductor depends largely upon the force of the current. Thus a telegraph circuit with its heavy out-door wire, its instruments and their light insulated wire connections, is sufficiently insulated to be operated by a light galvanic current without loss. But the approach of electric clouds may so charge the circuit as to burn out the instruments and make it unsafe for the operators. So we may understand that a sufficiently insulated conductor for a nervous current may be constructed of materials which are not absolutely non-conductors of electricity. The current takes the direction of least resistance which is along the nerve rather than across it. The resistance to galvanic conduction *across* a fibre of living nerve, is five times as great as the longitudinal resistance, and across a muscle fibre it is seven times as great as it is lengthwise. (Landois and Stirling.)

Whatever lack of perfection there may be in the insulation of the nerves, and particularly their ultimate fibrillæ, it is compensated by the character of the terminal organs themselves, whether muscle fibres, glands, or nerve or cerebral cells. The character of each of these organs is such that it is susceptible to only a certain *quality* or pitch of stimulation, and unless assailed by that particular sort of stimulation will not respond in normal action. This I believe to be especially true of the sensory receptive organs in the brain, which there is reason to believe are deaf and blind to every tone not exactly pitched to correspond with their fundamental, or the tone by which their differentiation was effected, as it is obviously true of the external sensory organs.

Nerves are variable in their facility of excitation—one nerve differing from another in this respect, one part of the same nerve differing from another part, and the same nerve differing from itself at different

times. When by the decay of the motor nerve its excitability is gradually lost, this loss begins at the upper end, or end nearest the center of sensation, and gradually passes down toward the muscle and after the nerve is dead above, it can still be irritated below, till at last when it is dead throughout its length, the irritation of the muscle can be effected by direct application of the electrical current to the muscle which continues alive much longer than the nerve. But when both nerve and muscle are fresh, the muscle is much more susceptible of irritation through the nerve than by the *direct* application of the electrical stimulus. The upper part of a living nerve is more excitable than the lower part. This has been proved in the case of living frogs and living men. When a nerve is cut and the excitability of its lower part is tested, the most excitable point is a little ways from the cut end, at which point the excitability increases for a short time and remains stationary for a while before it begins to decline. Both nerves and muscles become exhausted by over activity and recover somewhat by rest. Evidently in their normal place in the living body the exhausted tissues are recuperated from the nutritious matters brought in by the blood, and can be renewed indefinitely and completely, and even more than completely within limits in that way. But in the case of detached nerve or muscle when one excited point is exhausted, its recovery must be at the expense of the other unagitated and unexhausted parts. Each recovery of these detached nerves and muscles is feebler and less complete than the preceding one, till finally there is no further recovery, all the wearing tissue presumably being consumed.

Nerve dies in 10 or 15 minutes in a temperature of 44° C, and in a few seconds at 75° C. But at the average temperature of a room the lower ends of a long sciatic nerve of frog may retain their excitability for twenty-four hours longer. The more quickly and suddenly a stimulus is applied to a nerve, the greater the excitement. Every sudden pressure on a nerve will produce a stimulation of it, but it is possible by a gradually increasing pressure on the nerve to entirely crush it without producing any excitement. It is possible to produce tetanus by gently tapping the nerve with a little hammer. If a nerve attached to one gastrocnemius (A) of a frog be placed upon another gastrocnemius (B) so as to touch both a positive and negative point of tension on B, then if B be irritated a pulsation will take place in A. (*Rosenthal.*) The heart of a frog continues to beat for some time after it has been extracted from the body. If the nerve of a muscle is placed on this heart so as to touch its base and point, the muscle pulsates at every beat of the heart. This appears clearly to be a case of electrical induction. If the muscle B is irritated with such rapidity as to produce tetanus in it, tetanus is also produced in A. Induction takes place through the best

insulators, so that insulation of the nerve which prevents its normal current from leaving it is no bar to its influencing or being influenced by electric action in another body if near enough.

The nerve differs from the muscle in the fact that when it is excited it simply conveys the excitement to the muscle without itself contracting. But the muscle when excited contracts, thereby doing work. Each muscle fibre has its corresponding nerve fibre, and it is shown that the ultimate subdivisions of the nerve fibre, called the fibrillæ, penetrate among the fibres of muscles, and each muscle fibre finally is reached by one of these fibrillæ, the nerve fibres dividing and subdividing so as to make enough to go around. "When near the muscle fibre, the nerve suddenly becomes thinner, loses the medullary sheath, then again thickens, the neurilemma coalesces with the sarcolemma of the muscle fibre, and the axis-cylinder passes directly into a structure which lies within the sarcolemma pouch in immediate contact with the actual muscle substance, and is called the *terminal nerve plate.*" (Fig. 239.) This nerve plate is like a scab on the bark of the muscle fibre of mammals. In other animals it is different. In the frog, the nerve fibres penetrate into the sarcolemma, where they form a network, bringing their materials into direct contact with the matter of the muscle. The nerve fibres, insulated as they are by the neurilemma, pass among the muscle fibres without appearing to affect any of them except the ones to which they are directly connected by the nerve plate, or otherwise.

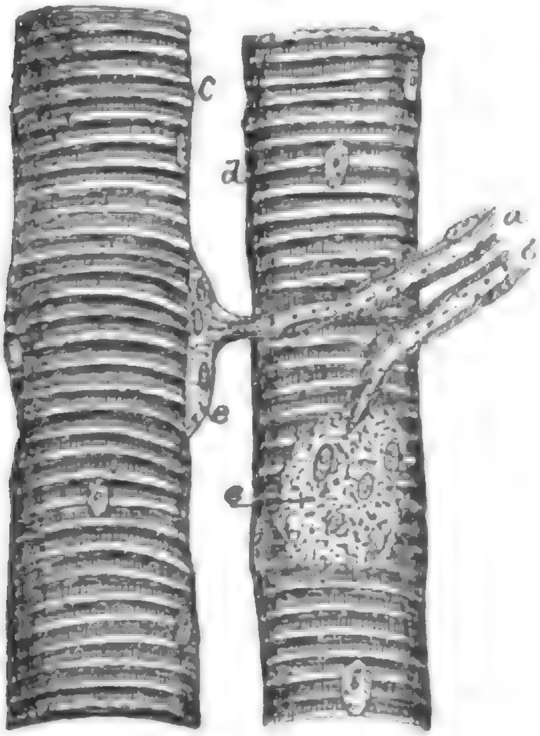


FIG. 239.

FIG. 239.—*Two Muscle Fibres of a mammal, showing their connection with nerve fibres.*
c, d.—The Muscle fibres.
a, b.—The Nerve fibres.
e.—The terminal Nerve Plate.
The dotted center of the nerve fibre is the axis cylinder, next, outside of which is the medullary sheath, which ends before reaching the muscle; and outside of all is the *Neurilemma*, which merges into and combines with the *Sarcolemma* of the muscle.

The poison curare (or wourali), which is obtained from the bark of a species of convolvulus, is used by the Indians of South America for poisoning their arrows. Its effect is to prevent muscular contraction. It is shown that neither the power of the nerve trunks to convey stimulus, nor the power of the muscles to contract when stimulated, is injured by this poison. The injury, therefore, consists in depriving the nerve of the power of delivering the stimulus to the muscle. This is doubtless due to the fact that near the point where the nerve fibre expands into the plate or "scab," above described, it is divested of its

fatty medullary sheath and is more exposed to the contact of the blood containing the poison. The poisoning at this point, therefore, has the same effect as cutting the nerve in two. It disconnects the circuit and breaks the current. The poisons nicotine and conine (tobacco and hemlock) have the same effect as curare. The effect of strychnine is to intensify the action of the nerves in converting and transmitting the stimulating action. They become so sensitive to external irritation that the slightest stimulus, even a breath on the skin, is sufficient to stimulate into tetanus all the muscles of the body. (*Rosenthal.*)

The nerves heretofore chiefly considered, are the *motor* nerves for moving the muscles. The office of the *vaso motor* nerves, which act on the smooth muscles, is similar to that of the motor nerves. They excite contractions in the muscle fibres whereby the vessels, of which they are a part, become reduced in diameter. The nerves which enter the *glands* produce a different effect; and so do the afferent or sensory nerves which connect the sense organs with the central ganglions of the brain and spinal cord. Yet there is no anatomical difference peculiar to any of them, to be discovered between the various nerves, whatever their office. The effect of irritants on detached nerves, is the same on all, but the manner in which the organs in which the nerves terminate are affected, differs according to the nature of such terminal organs.

Nerve fibres, like muscle fibres, are positive in the middle and negative on the ends. When a nerve is agitated, no perceptible molecular change takes place, and the only evidence of such agitation, accessible to the observer, is that which he gets by testing the electric condition of the nerve. By this means it has been ascertained that when a nerve is irritated at any point between its ends, the irritation travels in both directions along such nerve. If a motor nerve be agitated, its proper muscle will be contracted, and the stimulation will also flow backward toward the brain, without, however, exciting sensation there. If a sensory nerve, for example one of touch, be stimulated, the action on the brain will cause a sensation of touching something, but the backward flow toward the organ of touch will produce no effect in it.

Wier Mitchell says, "If we faradise[1] the track of the nerves in or above the stump" (after a hand has been amputated), "we may cause the lost fingers and thumb to seem to be flexed or extended." . . "In a case of amputation of the shoulder-joint, in which all consciousness of the limb had long since vanished, I suddenly faradised the brachial plexus, when the patient said at once, 'My hand is there again, it is bent all up and hurts me.'" "Persons who have had an arm amputated, are frequently able to will a movement of the hand, and apparently to execute it to a greater or less extent. A small number have en-

[1] Irritate by galvanic induction current.

tire and painless freedom of motion, as regards all parts of the hand. 'My hand is now open, or it is shut,' they say. 'I touch the thumb with the little finger,' &c."[1]

Every nerve fibre, while in its normal position in the body, excites in its receiving organ only one sort of action, no matter how the nerve may be excited. Thus the irritation of the optic nerve produces the sensation of light even when it is severed from the eye, provided its attachment to the brain is not disturbed. If a nerve be cut in two, its conducting power over the cut is gone, even if the two ends of the nerve are placed together. But a cut or bruise in a nerve is repaired by the natural healing process. Even if a piece of nerve as long as two or two and a quarter inches, be removed, it will be renewed. The repair begins by the nerve matter at one of the cut ends, forming into a grayish bunch and pushing along the former track of the nerve till it unites with the opposite end. To perfect such repair requires from four to six months. At first, the connecting section is more slender than the original, but by degrees it gets its proper size, and peculiar whitish color. (*Papillon.*)

According to Landois, the repair of a nerve depends on its connection with its central ganglion. This is the spinal cord, in the case of the motor nerves, and the ganglion of the posterior root, in the case of a spinal sensory nerve. These seem to be the headquarters for the nourishment as well as centers of the activities of their respective nerves, and repairs are propagated (chiefly) from them. Nerves have been diverted and given new connections. This is readily accomplished when a motor nerve is made to take the place of another motor nerve, or a sensory nerve of another of the same function; and it is held by some authorities to be possible even to connect a motor to a sensory nerve.

The size of nerve fibres in different animals, according to Todd's measurement, is as follows:

Fishes—Eel,	$\frac{1}{1043}$	of an inch in diameter.
Reptiles—Frog,	$\frac{1}{1260}$ to $\frac{1}{2280}$	" " "
Birds,	$\frac{1}{2000}$ to $\frac{1}{3000}$	" " "
Mammals,	$\frac{1}{1625}$ to $\frac{1}{6500}$	" " "

These are for the final fibres which do not divide or branch. (*Owen.*)

[1] Ferrier, Functions of Brain, 388.

CHAPTER LIII.

ACTION OF THE HEART.

A study of the comparative development of the heart and vascular system, shows that they have been built up by the circulation of the blood. Movement of a nutritive fluid takes place before it can be called blood, and before there are any vessels for its conveyance. The necessity for the movement of nutritious matter begins as soon as an animal is so large that some of its cells are interior, that is, when they no longer form a part of the external surface. As the animal form increases in size, and habitual activities are put upon it, the courses taken by nutritive fluids to reach the interior parts, become definite and fixed, and are formed into tubes. The original cause of the movement of the nutritive fluid must be attributed to the chemical attraction of the molecules of which the tissues are formed, for the new elements contained in the fluid. This of itself would cause a circulation, the attracted particles crowding past the discarded effete atoms, and thus pushing them to the rear. Chemism and electricity are only two forms of one energy, and when the former is in activity, the latter is invariably developed. In all probability, the very earliest circulation is stimulated by electric differences of potential, because electricity would be generated by differences of temperature in different parts of the circuit, by the chemical exchanges, and by the mechanical movement of parts engaged. Electric tensions would tend to relieve themselves by the mechanical contraction of the parts, which would involve the tubes conducting the fluid, and thus establish pulsations which would become periodic and rythmical in proportion to the regularity of the habits of the animal. As the animal increases in size, and the parts to be supplied with nourishment are of greater extent, the rythmical contraction of the vessels becomes an important and finally a necessary factor in the propulsion of the current.

In the processes of differentiation, certain parts of the circulatory canal become more contractile than others, and these parts constitute the rudimentary form of the heart.

The formation of channels, of greater or less consistency, through porous tissues, takes place very readily. This is seen on a large scale in the subsoil drainage of wet land. A subsoil ditch becomes the receptacle of innumerable little underground veins, which are constantly being extended by water pouring into their inner extremities, and branched into innumerable ramifications by veinlets pouring into their sides. As the water percolates from the surface after every shower, it falls into

these ready made channels and contributes to their enlargement, and such a soil becomes a network of quite constant veins and capillaries.

Landois says: "Intercellular blood channels of narrow calibre and without walls, occur in the granulation tissue of healing wounds. At first, blood plasma alone is found between the formative cells, but afterward, the current forces blood corpuscles through the channels. The first blood vessels in the developing chick, are formed in a similar way from the formative cells of the mesoblast." The arteries which carry the blood to the tissues from the heart, subdivide repeatedly until they become reduced to mere capillary threads. The tissues of the body generally are traversed in all directions by capillary blood vessels which form an intricate network. The veins also are connected with the capillaries, and drain the blood from the tissues back to the heart. The capillaries are from $\frac{1}{5000}$ to $\frac{1}{1500}$ of an inch in diameter. In many of them the blood corpuscles which pass through them are obliged to go single file, as there is not room to go abreast. The capillaries are composed of protoplasm apparently but little differentiated. One authority describes them as "protoplasm in tubes." This is their condition especially in the young animal. The walls of the capillaries are contractile, especially the nuclei of their cells. The walls are very thin and delicate, and accommodate themselves to the pressure of the contained blood. The larger blood vessels are likewise yielding and readily distended, but persistently regain their accustomed size when the pressure is taken off. The fibrous cells composing the thick walls of the larger vessels, like all others, require to be nourished, and so there are little blood vessels called *vasa vasorum*, which run through these coats and bathe all the cells. The coats of all the vessels being composed of cells which, in their original character, possess the individuality and contractility of so many amœbæ, the general contractility of the organ composed of them is accounted for as the sum of that of the individual cells exerted under a simultaneous impulse. The impulses are made common and simultaneous by the nervous system. The fœtal heart, like the other blood vessels, is composed of cells not modified into muscle fibres, and it beats for a long time before such modification takes place. There have been cases in embryonic growth, in which no heart was formed, but in which circulation nevertheless took place, producing a normal development of most of the parts of the body, so that contractility and circulation precede hearts. Furthermore; "It has occasionally been noticed that a gradual degeneration in the structure of the heart has taken place during life to such an extent that scarcely any muscular tissue could at last be detected in it, but without any such interruption to the circulation as must have been anticipated if this organ furnished the sole impelling force." (Carpenter.) And so we perceive that con-

tractility and circulation may also survive a partial unwinding of heart development. The heart is primarily only a portion of the system of vessels, which, from its position in the body, is exposed to more powerful or more frequent stimulations than other parts, and so has come to acquire a more constant habit and a greater facility for contraction, which has become settled and intensified by ages of use, while the contractility of most the other vessels has, by disuse, remained in a backward condition.

In some of the mollusks, contractile vesicles are found in different parts of the circulatory system. The Amphioxus has no heart, but its blood vessel contracts rythmically, thus propelling the blood. In the Ascidian, the heart is a dilation of the principal tube containing the blood, and by its contractions the blood is sent in both directions, a part going forward to the gills and becoming oxidized, and a part going backward into the tail end of the body and being deoxidized, the two bloods meeting in the heart when it dilates, and, to some extent, changing places for the next pulsation. No doubt the intermingling of these two, generates the greater part of the electricity which causes the contractions of the organ. The heart of the fishes is two-chambered, and the blood flows in at the auricle, which, by its contraction, drives it into the ventricle, which, in turn, drives it to the gills for oxidation. (See fig. 26.) The heart of the frog has three chambers, two auricles and one ventricle. The blood from all the veins, (two superior and one inferior venæ cavæ) enters the right auricle through an ante-chamber called the *venous sinus.* The blood from the lungs enters the left auricle. Both auricles drive their blood into the ventricle, which in turn drives it out into the aorta through a muscular swelling called the *bulbus arteriosus.* A branch of the aorta takes part of the blood to the lungs, while the rest is conveyed to all parts of the body. There are three nerve ganglions in this heart, one in the venous sinus and the others on the auricles. They are connected with each other and with the central nervous system by way of the vagus nerve. They no doubt correlate the movements of the different chambers of the heart so as to preserve the due sequence of contractions, although they were not originally essential to cause the contractions. Any part of the heart can be made to pulsate by direct stimulation by pricking with a needle, electric shocks, &c. The reptile heart has two auricles, one receiving blood from the body and the other from the lungs. It has one ventricle, but it is partly divided into two, and the aorta and the lung artery leave these separately. In the crocodile, the ventricle is fully divided.

The human heart, like that of the birds and mammals, has four fully formed chambers. The right auricle and ventricle are connected with each other, but are wholly separated from and independent of the left

auricle and ventricle. The whole heart of any person is about the size of his closed fist; according to Huxley. Each of the four cavities has the same capacity of from four to six cubic inches. Its whole weight in the adult is 8 to 9 ounces. The blood from the veins of the general system enters the right auricle, which, as soon as it is full, contracts and drives the blood into the right ventricle through a passage way, which is closed by the tricuspid (three-pointed) valve. This valve is composed of three triangular flaps, the bases of which are attached in a ring to the inside walls of the heart, while the long pointed ends project into the ventricle. These points give way before the incoming blood from the auricle. As soon as the right ventricle is full it contracts, and the pressure instantly closes the tricuspid valve, which is prevented from becoming inverted into the auricle by a number of fine, strong, tendinous cords, which connect the points of the flaps with portions of the walls of the ventricle. They are the *chordæ tendinæ*. The blood thus forced out of the right ventricle goes up the pulmonary artery to the lungs. The ventricle then dilates again, at the same time receiving an-

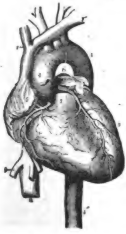


FIG. 240—*Heart and large vessels seen from the front.*
1.—Right ventricle.
2.—Left ventricle.
3.—Root of pulmonary artery cut short
4, 4′.—Arch of the aorta.
4″.—The descending aorta.
5.—The appendix and front part of right auricle.
6.—Same, of the left auricle.
7, 7′.—Innominate veins joining to form the vena cava superior—which extends from 7 downwards to the auricle.
8.—Inferior vena cava below the diaphragm.
9.—One of the large hepatic veins.
+, +.—Left coronary artery. The right coronary artery is seen to emerge from the aorta between 3 and 5. (*R. Quain.*)

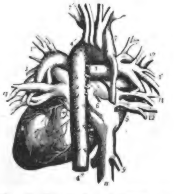


FIG. 241.—*Heart and great vessels seen from behind.*
1.—Right ventricle.
2.—Left ventricle.
3.—Right pulmonary artery.
3′.—Its branches passing into the root of the right lung.
3″.—Same of the left.
4′.—Arch of the aorta.
4″.—Descending aorta.
5.—Right auricle.
6.—Is on the division between the right and left auricles.
7.—Superior vena cava.
7′.—Left innominate vein.
8.—Inferior vena cava.
9.—Right hepatic vein.
10, 11, 12.—Right pulmonary veins.
13, 14.—Left pulmonary veins.
+, +.—Branches of right and left coronary arteries. (*R. Quain.*)

other charge from the auricle; and the blood just driven up the pulmonary artery is prevented from coming back into the ventricle by three fleshy flaps hung to the sides like swinging gates, which are instantly closed by the weight of the blood falling back toward the ventricle. These are called semilunar valves, from their *half-moon* shape. After passing through the lungs the blood returns down the pulmonary vein and enters the *left auricle*. This vessel then contracts and drives the blood through the *mitral* valve into the left ventricle. The mitral valve consists of two triangular flaps, one on each side of the passage; and when they fall together they close the way against the return of the blood into the left auricle upon the contraction of the ventricle, which it tends to do. The mitral valve is provided with the supporting cords, like those of the tricuspid. When the left ventricle contracts, the blood is forced into the aorta, and through the arteries into the general system. The ventricle dilates and is filled again from the left auricle, while the blood in the aorta is barred from returning to the ventricle by semi-lunar valves, like those in the pulmonary artery.

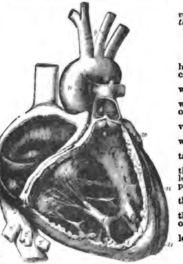


FIG. 242.—*Interior of the right auricle and ventricle, exposed by removal of a part of their right and anterior walls.*
1.—Superior vena cava.
2.—Inferior vena cava.
2'.—Hepatic veins.
3.—Septum separating the auricles.
3'.—Oval fossa. (In the fœtus there is a hole at this place between the two auricles.) Just below it is the Eustachian valve.
3''.—Entrance of the great coronary vein, with its valve.
+, +.—Auriculo—Ventricular groove, with a narrow strip of the adjacent walls of the auricle and ventricle remaining.
4, 4.—On the septum in the cavity of right ventricle.
4'.—Large anterior papillary muscle to which chordæ tendinæ are attached.
5, 5', 5''.—Left, right and posterior or septal segments of tricuspid valve.
6.—Inside the pulmonary artery—part of the front wall having been removed. Below the figure is a strip of the wall and the pulmonary valve.
7.—On underside of aortic arch close to the cord of the ductus arteriosus.
8.—Ascending part of the aortic arch—the lower part is covered by the appendix of the auricle and the pulmonary artery.
9.—Placed between the innominate and left common carotid arteries.
10.—Appendix of the left auricle.
11, 11.—Left ventricle.
(*Allen Thomson.*)

The heart is composed of muscle fibres, *striated* like those of the active muscles of the limbs, &c. But the fibres are destitute of the sarcolemma, or sheath, which striated muscles usually have. These fibres are in layers in the different parts of the heart, some lying in one direction and some in another. The walls of the different parts vary from each other in thickness. The average thickness in adult men of the right auricle is one-twelfth of an inch, or one line. The right ventricle averages about two lines, the left auricle about one line, and the left ven-

ticle from four to six lines. These different thicknesses indicate the different degrees of strain they are subjected to. The auricles have light work in simply filling the empty and unresisting ventricles. The work of the right ventricle in sending the blood only the comparatively short distance to the lungs is also light; but that of the left ventricle in driving it to the extremities of the body is much heavier, and it is a correspondingly stouter muscle.

There are nerves and ganglions in the heart which serve to co-ordinate the contractions. In the frog the dominating center is in the auricles, or in the septum between them, and while the heart is in running order, the due rythm and sequence of contraction is maintained. In man the two auricles contract simultaneously, and their contraction is immediately followed by the simultaneous contractions of the two ventricles. Then there is a slight pause, when the auricles contract again, and so on. From the central ganglia of the heart, fibres ramify to all parts of the heart and are said to connect with all the muscle fibres. If a frog's heart be detached from the body it will continue to contract in due rythmic sequence, but if the auricles be separated from the ventricle, both parts will continue their beatings, but at *different rates.* Parts of the heart which do not contain ganglia, pulsate as well as those which do. These facts prove that the ganglia only regulate the pulsations. After the heart of a rabbit is detached from the body, it may, under favorable conditions, pulsate for 36 minutes, and in one instance the last contraction of the auricle took place 15 hours after death. In a mouse's heart the last pulsation has been observed 46 hours after death, in a dog's 96 hours, in a frog's heart 60 hours, in that of a human embryo of three months, four hours. The right auricle is the last part to give up. The heart, like other muscles, is nourished and kept up by food supplied by the blood. It is furnished by two arteries, a right and a left, called the coronary arteries, which leave the aorta near its origin in the left ventricle. They send blood into numerous capillaries which ramify through the substance of the heart. The coronary vein conveys the blood, after it has done duty in the heart, back into the right auricle where it is thrown into the general circulation again. When a part of the blood was cut off from the heart of a large dog by the ligature of a large branch of a coronary artery, the ventricles ceased to beat in two and a half minutes, while the auricles continued to pulsate for several minutes longer. After a mammal heart has ceased to beat from exhaustion, it may be started up again by injecting fresh arterial blood into the coronary arteries. The left coronary artery of a man became plugged up so as to arrest the flow of blood into the heart, and his pulse fell from 80 to 8 beats per minute. (*Landois.*)

In order to produce the electrical motive power of any muscle, includ-

ing the heart, the blood and tissues must be in contact with oxygen and be burnt up by it. So, a detached frogs heart, which in a vacuum would beat 20 to 30 minutes, would in pure oxygen beat twelve hours; but in carbonic acid it would beat only ten minutes, and in chlorine gas only two.

The heart, like other muscles, is supplied with the polar energy necessary to cause its contractions by the oxidization of its own tissues and blood as the above cited facts abundantly prove. It differs from most muscles in the fact that its contractions are in general rythmical and continuous, while theirs are occasional, incidental and conditional. The muscles concerned in respiration are like the heart, ordinarily rythmical in their action, but may be interfered with and disturbed within narrow limits. The movements of the muscles concerned in digestion are conditional and casual, and ordinarily get their start from the contact and pressure of the food, and the force necessary to keep them up comes from the conversion of the chemical energy of digestion into electrical energy. Their activities are said to be automatic, and so are the activities of the heart and respiratory organs.

The heart is automatic to the extent that the force which causes its ordinary contractions is generated within it. The blood is thrown into the heart by way of the coronary arteries, and it is the consumption of the materials supplied by this blood that furnishes the motive power for the contractions of the heart. But it is these contractions which force the blood into the coronary arteries; so that each contraction makes provision for the next, and hence the perpetual rythm. There is considerable rythm in the movements of the intestines, which is kept up during the presence of the food products, but when these are consumed, the movement stops. But the heart does not stop, because the blood is never consumed. The force furnished by the blood delivered to the heart by the coronary arteries, is very much more than enough to run the heart alone. This is seen in the case of the frog's heart detached from the body, and so deprived of the blood supply. It then runs by force obtained by the consumption of its own tissues and the small amount of blood in them. But it runs light like an empty wagon. In the body it not only moves itself but propels a great load of blood to all parts of the system. The blood which is thus sent off to the other parts of the body, generates in them an amount of force proportional to that furnished to the heart by the coronal blood. This force is of a definite average amount in each individual; and it depends primarily on the size and organization of the individual, and secondarily, on the frequency and energy of the stimulations to which he is subjected from without. It is never enough to run all parts of the body up to their highest capacity at the same time, so that when there is call for a spe-

cial exertion of any part, that part must receive an extra or unusual supply of blood. As the ancient doctors stated it, *Wherever there is stimulation, thither flows the blood.* "Ubi irritatio, ibi affluxus." During the *activity of an organ* the amount of blood in it may be increased 30 per cent., or even 47 per cent; and generally the amount of blood in any part or organ varies to correspond with its condition of activity. (Landois.) The extra supply is obtained by an increase in the rate of pulsation, and this increase appears to be due to two causes. One cause is, that as soon as a part receives an extra stimulation, a part of the stimulation is communicated by the nervous system to the heart, causing extra exertion on its part, accompanied by a larger supply of blood to it by way of the coronary arteries. The other cause is mechanical, and results from relief of the pressure of the blood in the arteries. Whenever a particular part is active, the arterial blood in that place is more rapidly consumed, and the materials thus abstracted from the arteries, or an equivalent amount in the shape of waste matter, is thrown into the veins. This, by relieving the pressure against which the heart works, allows it to work faster. The whole arrangement is very much like a system of city water works, where the pressure is maintained in the pipes by the pumps. The pipes are the arteries, and the thousands of outlet cocks used by consumers, are the fine capillaries or hair-like tubes into which the arteries subdivide in the tissues of the body; the sewers are the veins. The strokes of the pumps fluctuate with the demand for water. In the night they are slow, faster in the day-time, fastest if an extraordinary demand arise, as in case of fire. So, the circulation of the blood and the pulsation of the very pump-like heart are slow at night, when, in sleep, the activity of the body is reduced to a minimum. For the ordinary duties of the day the pulsation is increased, while an extraordinary exertion may almost double it. A middle aged man may, in a few minutes, by violent exercise, raise the pulse from 70 to 110, and the respiration from 18 to 28 per minute. The ordinary pulse steadily declines in rapidity from infancy to old age. It is most rapid during the period of the relatively most rapid growth and greatest activity. It is stated by some authorities to be 140 per minute at birth, at the age of one year, 120, at three years, 100, at twenty years, 85, in the middle of life, 70, and in old age, 50 to 60.

As mentioned above, the nervous ganglions in the heart are connected with the general nervous system of the body, by means of which connection the condition of the body has more or less influence on the action of the heart. The chief of these connections are a branch of the pneumogastric or vagus nerve, and branches from the three cervical ganglia and the first thoracic ganglia of the great sympathetic nerve. The first of these is called the *inhibitory* nerve of the heart, because when it

is stimulated the first effect is a check or stoppage of the beating of the heart. The last one is the *accelerans*, so called because when it is stimulated the heart moves faster. In regard to the inhibitory nerve it appears that it is not inhibitory in the long run; "but that it ultimately improves the condition of the heart as regards force, rate, or regularity —one or all of these;" so Gaskell, the best authority on the subject, regards it as a true "anabolic nerve." The roots of the vagus nerve are in the medulla oblongata, and here there is a mass of nervous matter which is a center of sensation for the visceral parts of the body. The vagus nerve is both motor and sensory, and this center is the organ for receiving the sensory reports of the state of the viscera and various other organs, and reflecting them to motor organs with which they are related, among which is especially the heart. When certain organs served by the vagus nerve are in a condition to need more blood, the current up the sensory nerve from such organs to the center in the medulla is such that it excites the so-called inhibitory nerve, down which a stimulus goes to the heart. This organ then works a little harder and so furnishes the lacking aliment. (It may be that the stimuli used in the experiments on the inhibitory nerve were too strong for it and dazed the heart at first, as the eye is dazzled by a too sudden avalanche of sunlight from which it, however, soon recovers.) The accelerans nerve probably acts for some other organs to stimulate the heart in their behalf. Of these two classes of nerves Dr. Ferrier says: "The inhibitory nerves may be stimulated and the heart restrained by powerful irritation of the sensory nerves of the surface generally, by irritation of the sensory branches of the fifth in the nostrils, by irritation of the sensory nerves of the larynx; and in particular by irritation of the intestinal sensory nerves. Thus a smart tap on the intestines of a frog causes the heart to stop, a fact which serves to explain the danger of blows on the epigastrium, and the fatal consequences which, in certain conditions of the system, sometimes follows the sudden shock of a large draught of cold water or irritant poison on the sensory nerves of the stomach. The accelerator nerves can be excited reflexly by stimulation, among others, of the afferent nerves of the muscles, a fact which may partly have to do with the increased rapidity of the heart's action during active muscular exertion." Dr. Brunton thinks the inhibition is due to the interference of molecular vibrations by the different nerve currents.

During active muscular exertion it is shown that the blood vessels of the muscles become distended and have a greater quantity of blood in them. There is a nerve center in the medulla oblongata called the *vaso-motor center*. It is the starting point for the motor nerves which supply the blood vessels of the arterial system. These vessels are simply tubular muscles, and when a large number of them are stimulated, their

contraction reduces the size of the tube and thus causes increased blood pressure. Under these circumstances the heart is made more active, the pressure probably forcing more blood into the heart muscles through the coronary arteries, and thus stimulating and at the same time supplying them with greater power.

CHAPTER LIV.

ACTION OF GLANDS.

The glands are similar to the muscles in many respects though their structure is different. "A gland of the simplest form is a cavity lined with cells opening by a longer or shorter passage through the outer surface of the mucous membrane or the outer skin (corium), which lies above it. The cavity may be hemispherical, flask shaped, or tubular. In the latter case the tube is often very long, and is either wound like a thread or is coiled and is sometimes expanded at its closed end in the form of a knob. These are all *simple glands*. *Compound glands* are found when several tubular or knob-shaped glands open with a common mouth." (Rosenthal.)

These glands are variously occupied in secreting from the blood various substances—sweat, fat, saliva, gastric juice, gall, bile, urine, milk, tears, &c. When any nerve connected with a gland is irritated the gland becomes active in its function of secretion. "If, for example, the nerves which pass into the salivary gland are irritated, the saliva may be made to ooze in a stream from the mouth of the gland." The simple glands, like the muscles, possess regular electric activity. Where a large number of the simple, bottle-shaped skin glands "occur regularly, arranged side by side, it is found that the lower surface, that which forms the base of the glands, is positively electric, while the upper surface, that which forms the exit duct of the gland, is negatively electric." (Rosenthal.) When glands are irritated and made active the "negative variation," or decrease of gland current, takes place the same as in the muscle. That is, electrical tension disappears in work. The mucous membrane of the stomach and intestinal canal also furnishes electrical action, according to experiments on the alimentary canal of the frog. The direction of nervous energy to any of the glands, stimulates their normal activity. This can often be accomplished by simply directing attention to the organ, or to some act in which its functions are concerned, for, as will appear further on, mental action may become current electricity. Even mere states of feeling may produce effects on certain glands when there is neither attention nor consciousness of them or their functions. The secretion of milk in the mammary glands of a

mother, is often largely stimulated by the anticipation of suckling the infant, or even thinking about it. The secretion of milk during pregnancy, appears to be due to nervous stimulus sympathetic with uterine activity; an association dating back to the earliest types of mammal life, and even beyond. The mental state of the mother has an effect on the quality as well as the quantity of the milk. It is affected by a fretful temper, by fits of anger, by grief, by anxiety of mind, by fear, by terror, and by excessive indulgence of the passions and appetites. Examples are given in which infants have been fatally poisoned by milk which has been changed in the mother's breasts by her violent emotion or mental excitement. A case is given of a puppy which was seized with epileptic convulsions on sucking its mother after she had been in a fit of rage. (Carpenter.)

Other secretions are equally subject to nervous stimulus effected through mental action. Experiments upon dogs and pigs, show that after they have been kept fasting awhile, a sight of food, which they are not allowed to eat, provokes a flow of gastric juice into the stomach. It is familiar to all, that the flow of saliva, the action of the lower intestines, the secretion of the kidneys, sexual secretions, tears, &c., are influenced by mental states. These facts are based on the nervous connection between the secreting glands and the general nervous centers—brain and spinal cord.

The sweat glands are subject to the influence of the nerves, like the salivary glands. It has been observed, that in amputated limbs, if the distal ends of the nerves be irritated, a copious exudation of sweat may occur. The sudoriparous, or sweat glands, have their nervous connection with the spinal cord corresponding with the nerves of general, sensory and motor innervation. They are reflex, and can be operated when the spinal cord is severed from the brain; and they are also controlled by mental states. The number of these minute glands is estimated at two and a half millions, giving a secretory surface of nearly 1080 square meters.

(A number of facts relating to the glands concerned in digestion, have been mentioned in Chap. 28.)

In general, glands are stimulated to action by the direct contact and pressure of the substances they operate with, or reflexly through nervous stimulation coming from other organs with which they are in working relationship. The development in animals of both muscles and glands, has been imitated, to a greater or less extent, by corresponding parts in a few of the plants. Or, perhaps it would be more accurate to say that the functions of muscles and glands, and even nerves, are performed in certain plants by the cells of plants without any very distinct specialization of the tissues. Most of the facts in this chapter, relating

to plant movement, we owe to the researches of Darwin. They prove to us the easy disposition of protoplasm to be moulded into such organic structures under certain conditions.

Insectivorous Plants. There are a good many plants that derive more or less of their nourishment from animal food, and they are fitted out with some special apparatus by which they are enabled to get its benefit. The Pitcher Plant (Sarracenia), which is common in our swamps, has leaves which are shaped like a deep, narrow cup. These leaves are usually half full of water, which is pretty sure to contain a lot of drowned insects. Their juices can hardly fail to be absorbed by the plant, and so assist in its nourishment. This is rendered the more probable from the fact that it is well settled that other plants do absorb the juices of insects.

The Utricularia, or Bladderwort, is usually a plant without roots, floating in the water, but some land species have also been described,

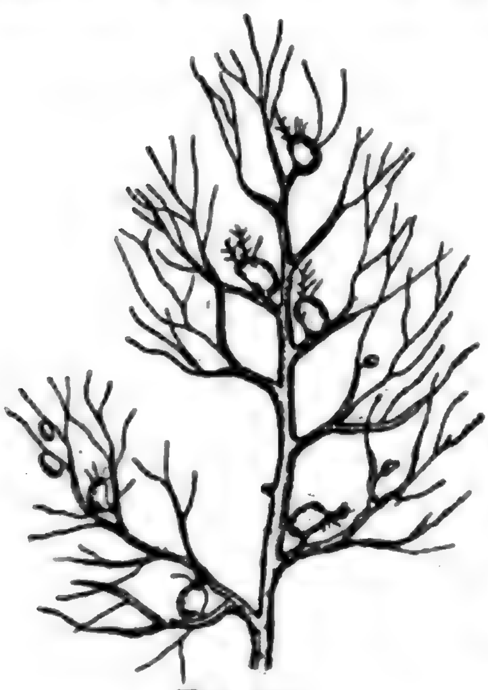


Fig. 243.

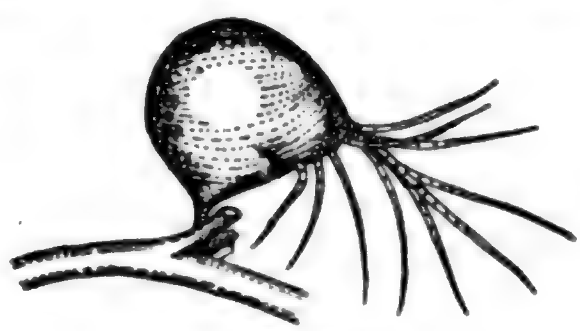


Fig. 244.

Fig. 243.—Branch of *Utricularia neglecta*, with divided leaves, bearing bladders.

Fig. 244.—*One of the Bladders of Utricularia neglecta*, showing the antennæ and entrance underneath.

having roots by which they are attached either to the soil or to other plants as epiphytes. Asa Gray describes thirteen American species, some of which are also found in Europe, and there are many more foreign species. The peculiarity of the plant is the little bladders (utriculi) which grow upon the leaves, generally near the base. These bladders are translucent, of a greenish color, and when grown are $\frac{1}{10}$ of an inch in diameter in some species, and $\frac{1}{5}$ of an inch in others. At the extremity of the bladder there is an opening or mouth, which is closed by a valve opening inwards. This valve is a thin, transparent, elastic flap, which is pushed in by minute crustaceans and infusoria as they enter, but which immediately closing back against the lip of the bladder, prevents them from returning. Around the mouth of the bladder are a number of arms, or processes, resembling antennæ, and together with the general shape of the bladder, giving it the appearance of a cypris or water-flea. The interior walls of the bladder are covered with little arms or processes, which Darwin calls quadrifid processes,

because they grow in clusters of four. Four arms take root at the same place, from a short pedicel, and radiate their extremities in four directions. Just inside the mouth the processes have two arms instead of four, and they are called bifid processes. Darwin ascertained that these arms have the power of absorbing some of the matters held in solution in the water inside of the bladder. The little animals getting in there, die and decay, and are dissolved in the water, and thus furnish subsistence to the plant.

The Butterwort (*Pinguicula vulgaris*), which belongs to the Bladderwort family, is found in Northern U. S. and Europe, and is another in-

FIG. 245.—*Two leaves of Pinguicula or Butterwort.*
a.—Right edge of leaf closing over bits of meat.
b.—Left edge closing over flies placed upon it.

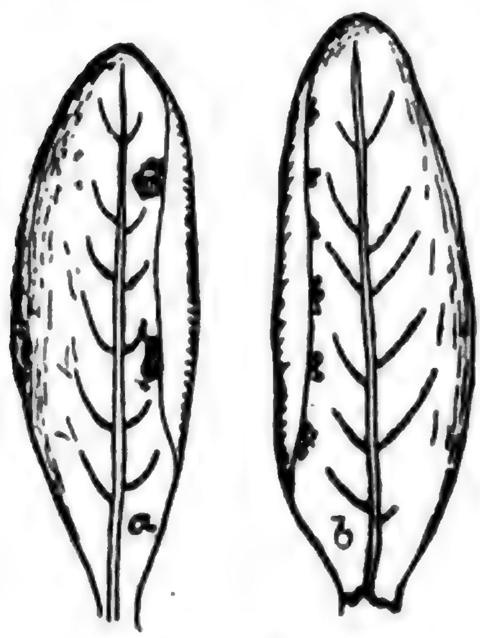


FIG. 245.

sect-catching plant. A grown leaf of this plant is about 1½ inches long and ¾ inch wide. About eight leaves radiating from a common center, some lying flat on the ground and others above them and standing nearly upright, form, on the whole, a sort of rosette. The margins of the leaves are curved inwards. The upper surfaces of the leaves, except the edges, are covered with glands supported upon pedicels. The glands secrete a viscid, colorless fluid, which is so sticky as to hold insects which happen to get on the leaf. This secretion becomes more copious and is acid when insects are caught. The secretion, when acid, "has the power of quickly dissolving, that is, of digesting the muscles of insects, meat, cartilage, albumin, fibrin, gelatine and casein, as it exists in the curds of milk." This secretion is, however, not able to dissolve starch. The secretion which was caused by depositing a piece of starch on the leaf, did not become acid. The presence of nitrogenous matters upon the glands, while causing them to secrete, also causes the margins of the leaves to infold toward the midrib, so as to inclose the object. If the object is near the end of the leaf, the edges opposite to it are incurved, while the edges further down the leaf are not affected.

The Droseraceæ, or Sun Dew Family, comprise six genera, all of which capture insects and digest and appropriate them. Three genera of them, viz., *Drosophyllum*, *Roridula* and *Byblis*, detain the insects solely by means of a sticky substance which they *secrete* from the *glands* upon their leaves. One genus, the Drosera, also has the viscid secretion upon which the insects stick, but the leaves are, in addition to this, provided with flexible filaments or tentacles, which, when an insect is caught,

slowly bend over and hug it to death. Two other genera, the Dionea and Aldrovanda, have leaves, the two lateral halves or lobes of which are united by a sort of hinge or midrib. When either of those is agitated by the pressure of an insect alighting upon it, they suddenly close, and generally catch the intruder, squeeze it to death, and absorb its sub-

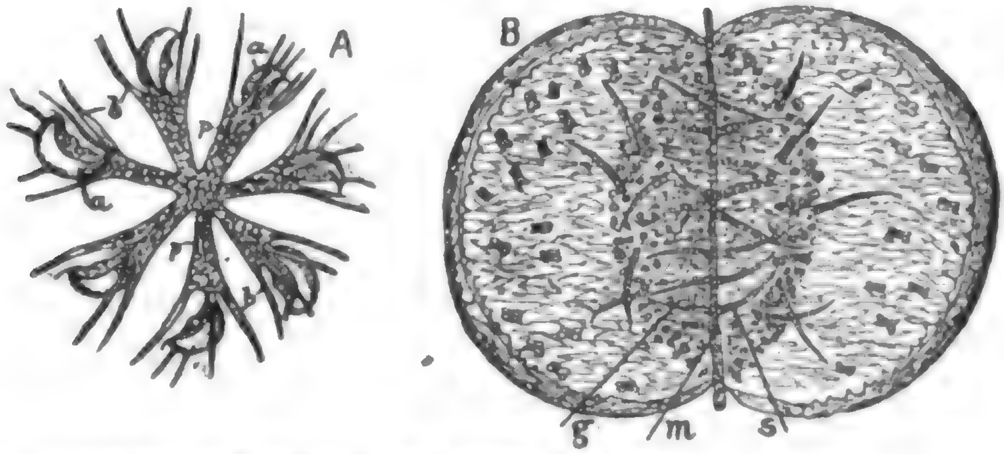


FIG. 246.—*Aldrovanda Vesiculosa, an aquatic fly-trap.*
A.—A whorl of leaves floating free. It is destitute of roots.
a.—Lobes of the leaf.
b.—Defending bristles.
p.—Petiole, or leaf stalk.
B.—Lobes of leaf enlarged and pressed flat open.
m.—Midrib.
g.—Glands.
s.—Sensitive hairs, Organs of Touch.

stance into the tissues of the plant.

The *Aldrovanda* is a water plant without roots, and floats freely. The bi-lobed leaf has, on the part near the midrib or hinge, a large number of glands, which are supposed to secrete a fluid which contains a ferment for digesting the animal matter squeezed out of the victims. In the same part of the lobes, and particularly on the midrib itself, are a large number of long, finely-pointed hairs, which are organs of touch, and when touched convey a stimulus which closes the lobes together. The lobes stand apart at a small angle, so they do not have to move far in shutting.

There is only one genus of the *Dionea Muscipula*, and it is found in eastern North Carolina. The common name is the Venus Fly-trap.

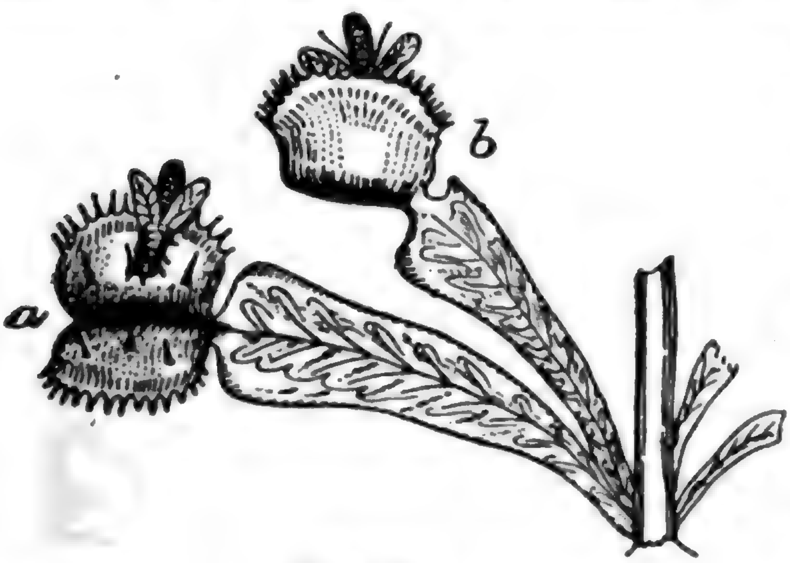


FIG. 247.

FIG. 247.—*Dionea, or Venus Fly-trap* attending to business.
a.—"Laying" for him.
b.—Got him.

"Each leaf bears at its summit an appendage, which opens and shuts, in shape something like a steel trap, and operating much like one." The two lobes of this trap open so as to stand usually at an angle of about 90° with each other. Around the outer edges of each lobe, is a row of stiff projections or spikes. On the inner face of each lobe there are two, three or four filaments, or hair-like processes $\frac{1}{20}$ of an inch long, which are

the organs of touch, for whenever they are touched by an appropriate object, as the legs or wings of an insect, the lobes of the trap fly shut, and generally catch the unlucky trespasser. The inner surfaces of the lobes are covered with small glands of a reddish or purplish color, in consequence of being composed of cells which are filled with a reddish fluid. These minute glands stand on very short pedicels. When a capture is made, these glands secrete a fluid, which is colorless, slightly mucilaginous, and quite acid. This secretion does not take place unless the glands are brought into contact with nitrogenous matter. When the lobes are closed upon an insect, or a bit of albumen or meat, the digestible portion is completely dissolved and absorbed by the plant, which takes several days for the process. But if the trap is excited to close itself by an insect which nevertheless makes its escape, or by an artificial stimulus, which leaves no food to be digested, it opens within 24 hours. The lobes of the trap are about half an inch, or a little more, in length, and they manage very often to catch beetles, spiders, &c., half as long as themselves. The closure of the lobes together, is due to the contraction of the cells on the inner faces of the lobes, and especially those near the midrib. The stimulation by which their action is excited, spreads rapidly from any one of the sensitive filaments, so that both lobes engage in the movement of closing at the same time. Dr. Burdon Sanderson discovered that there is a "normal, electric current in the blade and foot-stalk, and that when the leaves are irritated the current is disturbed in the same manner as takes place during the contraction of the muscle of an animal." Both lobes of the trap of the Dionea will close when any one of the six sensory filaments is touched, which shows that the stimulus spreads in all directions through the cellular tissues of the plant. And it crosses from one lobe to the other with great rapidity, for both close at once. Darwin's experiments failed to find any other organs than the cells themselves, that appear to be concerned in the transmission of the stimulus. The vessels do not transmit it, or at least not exclusively. Here then we have nervous transmission through tissues not yet differentiated into nerves, just as we have it in Cœlenterate animals. Other observers have agreed with Darwin that the stimulation passes from cell to cell, not only in the Dionea but in Aldrovanda and Drosera as well.

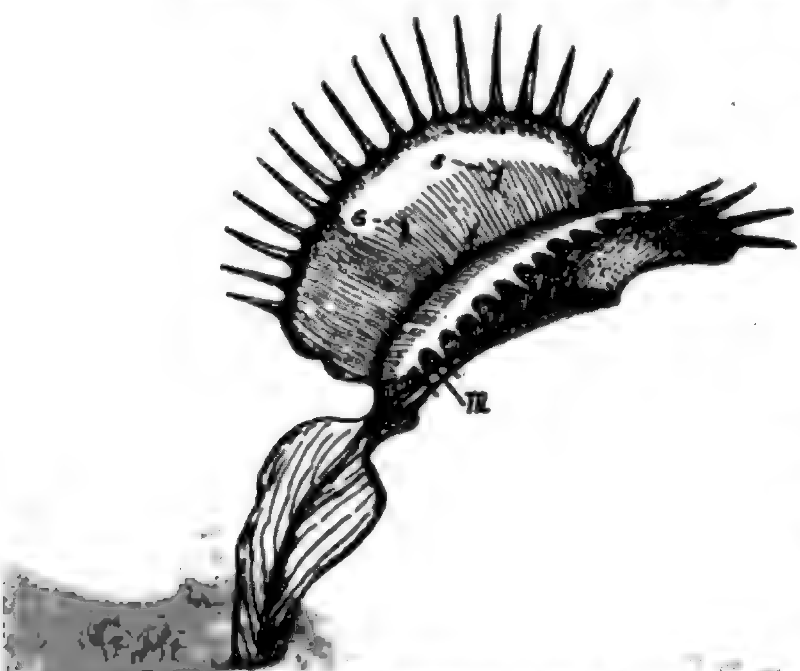


FIG. 248.—*Expanded leaf of Dionea Muscipula.* m.—Midrib. s.—Sensory hairs.

The *Drosera rotundifolia*, or round-leafed Sundew, is native both in this country and Europe. It is a remarkable plant, and has been exhaustively described by Darwin. (Insectivorous Plants.) The leaves of this plant are circular, a little over half an inch in diameter, and they are covered with glands which are set upon stalks or pedicels, a gland with its stalk being denominated a tentacle. The average number of these tentacles is nearly 200 per leaf. The tentacles in the central part of the leaf are short, and stand upright. They increase in length going outwards, and incline more and more outwardly until the margin of the leaf is reached, where they recline horizontally, and are sometimes nearly $\frac{1}{4}$ of an inch in length. The stalks of these tentacles are flexible, and contractile, particularly near their base, and under stimulation they bend over toward the center of the leaf, each carrying the gland on its summit with it. This gland is less than $\frac{1}{100}$ of an inch in diameter, and to it adheres the drops of viscid secretion which it distills, and the glisten of which in the sunlight suggests the name, sundew. When the tentacles in the central part of the leaf are agitated by being pressed and shaken, as by the struggling of an insect in the sticky secretion, a stimulation is conveyed to the tentacles on the margin of the leaf. "The nearer ones are first affected, and slowly bend toward the center, and then those farther off, until at last all become closely inflected over the object. This takes place in from one hour to four or five or more hours." The stimulation which travels from the tentacles which are agitated by the foreign substance, arouses both motor action in the stems of the marginal tentacles by which they are bent, and glandular action in causing the glands to secrete their fluid. This fluid contains a ferment, and is a peptic agent, and, as Darwin discovered, it also has an antiseptic quality, and prevents animal matter in contact with it becoming putrid. The tentacles remain clasped over nitrogenous matter much longer than over other substances, sometimes not re-opening again for seven days. But if they are stimulated to close by an agitation which affords nothing they can digest, they open again within 24 hours. The activity of the protoplasm in the tissues of Drosera, is shown by fig. 250.

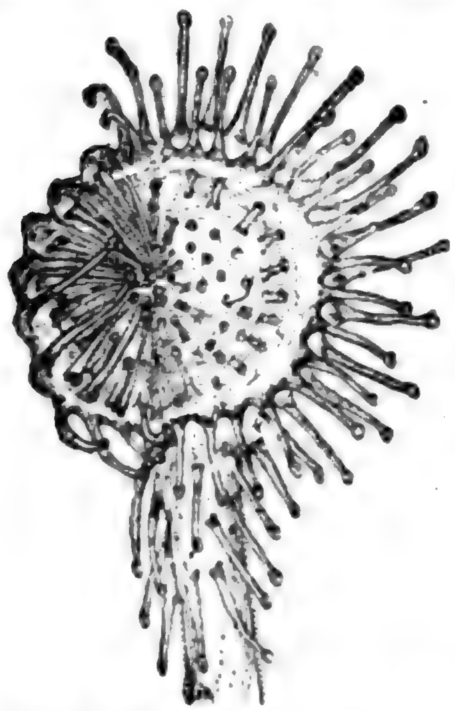


FIG. 249.—*Drosera Rotundifolia (round-leaved)*. Part of the tentacles curved over and holding down a piece of meat. (*Darwin*.)

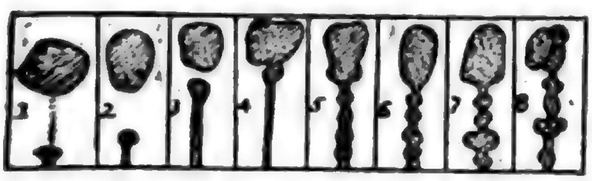


FIG. 250.—Eight different forms taken by the protoplasm in a cell of a tentacle of Drosera Rotundifolia, during a period of 15 minutes. (*Darwin*.)

We found in the study of fermentation, that plants possess the means for the production of one or more digestive diastases or ferments. In animals, the secretion of such ferments is performed by organs differentiated and adapted to that end. But the plant appears to secrete these ferments, in many cases, without the intervention of any distinguishable organs. There must be cells scattered through the tissues of plants, which produce these diastasic elements. In animals, these cells are organized into aggregations or organs. But in the insectivorous plants, the glands, or some of them, are also thus organized, and of several sorts, as it appears from the foregoing accounts. Thus, in these plants there is a beginning of that reciprocity of offices between differentiated parts, that is carried to such a great extent in animals.

CHAPTER LV.

ELECTRIC ORGANS.

The Muscles and Glands discussed above, are organs in which one mode of physical motion is turned into another; viz., Electricity into Work. There is another class of organs in which electricity is accumulated and *not* converted into work, nor silently discharged, as from ordinary muscles, as fast as formed, but in which it is accumulated under powerful tensions, and liberated in violent shocks at the will of the animal possessing the organs. These are called *Electric Organs*, and they are good means of defense to the animals owning them. The principal electric fishes are the electric ray (Torpedo electrica and Torpedo marmorata) of the Adriatic and Mediterranean, the Gymnotus electricus, or electric eel, of the fresh waters of S. America, and the Malapterurus electricus, or M. beninensis, from the bay of Benin on the west coast of Africa. The electric organs of all these are essentially alike. "They consist of a large number of minute and delicate plates, which, arranged side by side and enclosed in coverings of connective tissue, form the whole organ. In the Torpedo these organs lie flat on either side of the vertebral column. In the Gymnotus and the Malapterurus they are arranged longitudinally; and in the latter they form a

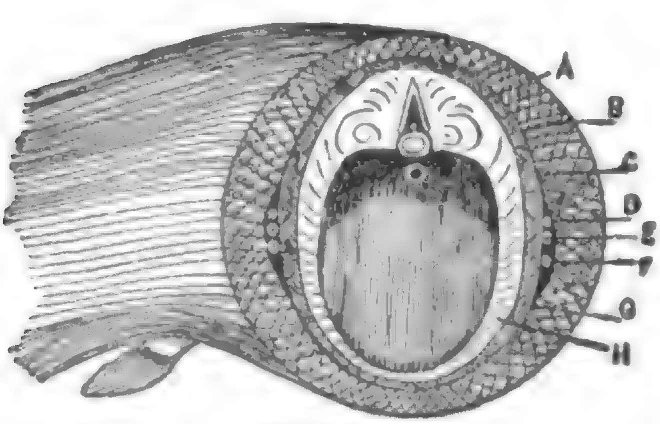


FIG. 251.

FIG. 251.—*Cross section of Malapterurus Electricus.*
A.—Skin.
B.—Electric Cells.
C.—Cellular Tissue.
D.—Nerve.
E.—Artery.
F.—Vein.
G.—Adipose (non-conducting) tissue.
H.—Muscles.
(*Owen, from Pacini.*)

closed tube in which the animal is concealed, its head and tail, as it were, alone projecting. The separate plates of which the organ consists, are arranged horizontally in the Torpedo, vertically in the Gymnotus. Each of these plates consists of an extremely delicate membrane, which, when the organ is in a state of activity, exhibits positive electricity on one side and negative on the other. The currents of the numerous plates combine, as in a battery, and thus all together afford a very powerful current. With each plate is connected a nerve fibre, by means of which the animal is capable of voluntarily effecting the electric discharge, just as voluntary muscular contractions can be effected by means of the nerve. These nerves may also be artificially irritated, with the result of producing one or more electric shocks, just as irritation of a motor nerve elicits one or more muscular contractions. The analogy of electric organs and of muscle is, in fact, from a physiological point of view, complete." (Rosenthal.)

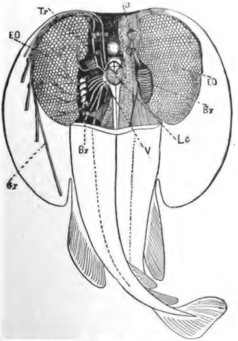


FIG. 252.—*Torpedo* (*Electric ray*). *Showing Electric Organs.* (*Gegenbauer.*)
On the right is shown the dorsal surface of the electric organ, on the left the nerves which go to it are shown.

E O.—Electric organ.
Br.—Gills—on the right they are covered by their muscular layer.
Tr.—Trigeminum, or 5th nerve.
Le.—Electric lobe of the brain.
Gr.—Gelatinous tubes of the skin (sense canals).
V.—Vagus, or pneumogastric nerve.
O.—Eye.

Besides the fishes named above, the following possess electric organs, the functions of which are, however, not so strongly developed; Mormyrus longipinnus, Mormyrus oxyrhynchus, Mormyrus dorsalis, Trichiurus electricus, Gymnarchus niloticus, and Tetraodon electricus. There are many others, the total number of species being about fifty. The electric plätes of the Torpedo are mostly hexagonal in shape, and being piled upon each other vertically they form hexagonal prisms, which extend from the skin of the back to that of the ventral side of the fish. The plates themselves consist of delicate membranes, and are separated from each other by flattened cells, each cell consisting of two layers of epithelium separated by a thin layer of limpid, fluid, albuminous matter. The hexagonal columns are separated from each other and from the skin above and below, by a thin envelope of glistening aponeurosis (a membrane). Between the epithelium of the flat cells and the aponeurotic partitions, is an unorganized layer, in which the nerve fibres and blood vessels terminate. The nerves form loops as they do in the muscles. In each of the two electric organs of the Torpedo, there are about 470 of the prismatic columns. The supply of nervous energy to these organs is very great, and is conveyed by one branch from the 5th pair of nerves (trigeminum), and four branches from the par vagum (10th pair). Four of these nerves are very large; each one exceeding the spinal cord in thickness. They enter the organs upon their inner edges, and as they pass through they cut in two some of the prismatic columns. They subdivide and send fibres to all the partitions between the prisms. There are enlargements of the olivary and restiforme bodies at the point where the electric nerves connect with them which have been, not very properly, denominated electric lobes. They are made up of the vagal and trigeminal enlargements of those nerves at their junction with the medulla oblongata. The Torpedo is from one to two and a half feet long.

In the Gymnotus, as mentioned above, the aponeurotic partitions lie horizontally, while the plates stand perpendicularly, reaching from one partition to another. Some of these layers are nearly as long as the whole animal except the head and tail. The ventral half of the animal consists of these electric organs, while the dorsal half contains the spinal column, muscles and air bladder. The digestive and respiratory apparatus, and reproductive and excretory organs, heart, &c., as well as the brain and organs of sense, all lie in front of the electric organs. The electric organs are four in number, two on each side. The upper one on each side is separated from the lower by a thin muscle layer and membrane. The upper ones are much larger than the lower ones. A median partition extending lengthwise through the animal divides the organs of one side from those of the other. This partition branches

below the air bladder, backbone, and muscle layers, one part extending to the skin on either side and separating these parts from the electrical apparatus below. The horizontal aponeurotic layers, before mentioned, extend from this vertical septum outward on each side to the skin.

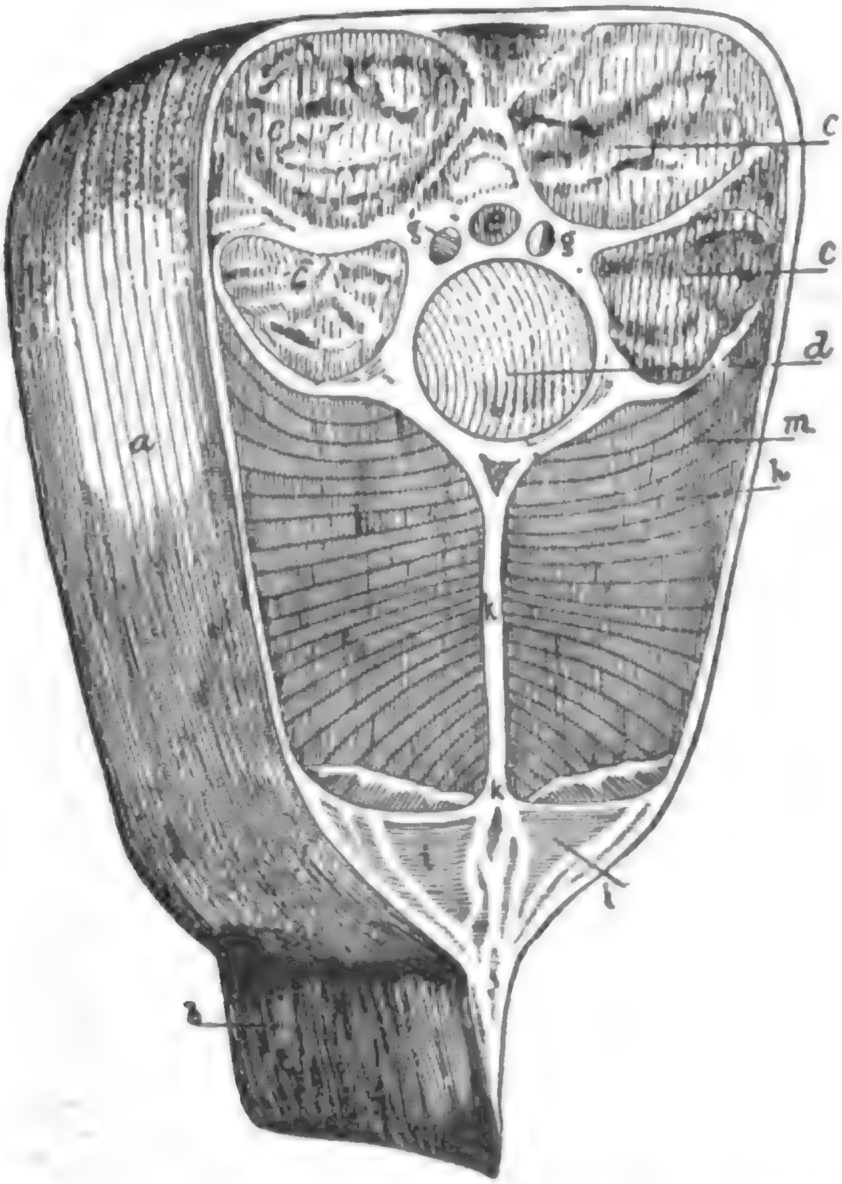


FIG 253.—*Vertical cross section of Gymnotus (Electrical Eel). Natural size. (Dr. Knox.)*

a.—Skin.
b.—Fin.
c.—Muscles.
d.—Air bladder.
e.—Backbone.
h.—Vertical electrical plates in upper organs.
m.—Horizontal laminæ separating the electrical plates.
i.—Lower electrical organs.
k.—Aponeurotic partition or septum.

They are as long as the organ, but as that runs to a point at the rear some of the layers are much longer than others. The vertical plates extend from the middle partition to the skin, and are therefore as long as the horizontal layers are wide. They are about half a line high at their outward ends next the skin, but somewhat less at their inner ends, as the horizontal membranes approach each other as they go inward. There are about 240 of these vertical plates to the inch, measured lengthwise of the fish. The spaces between these vertical plates is occupied by cells and a fluid; but their arrangement differs from that of the cells and fluid in the organs of the Torpedo, for in the Gymnotus the cells are in a double layer, which occupies the middle of the space between the vertical plates, the fluid being separated into two parts, one

before and the other behind the cells. The cells themselves are pyramidal, the apices of one half pointing into the precellular fluid, and those of the other half into the post cellular fluid. The cell layer is electrically positive, the fluid space in its rear and the vertical plates are negative. The fluid in front is neutral, and a conductor from one to couple to another. "The whole represents the ternary type of the voltaic pile. The Torpedo's structure is according to the binary type." (Owen.) The nerves running to the electric organs in the Gymnotus are supplied by branches from the spinal nerves, of which there are about 200 pairs. Filaments from these run down the middle aponeurotic partition and ramify thence upon the horizontal layers. Other filaments from the same nerves pass down the skin and reach the layers at their outer edges. This is a very different arrangement from that of the Torpedo, whose electric nerves are all from the encephalic pairs. But the organs of the Torpedo lie on each side of the head, while those of the Gymnotus are entirely back of the head and extend to the tail. In each case, the nerves engaged are those directly opposite the organs to be supplied. The electric eel is about seven feet long.

The electric organ of the Malapterarus is a hollow cylinder surrounding the whole body except the head and fins. Directly inside of the electric cylinder is another of cellular tissue, in which the nerves and blood vessels which supply the electric organs, are buried; inside of this cylinder is a third composed of non-conducting, fatty tissue. Within the fatty layer is the muscle cylinder, bearing the vertebral column and containing within its cavity the organs of the animal. (Fig. 251.) The battery cells of the electric organ are lozenge-shaped, about a third of a line in size, and separated from each other by fine membranes. The nerves supplying this organ originate from the upper end of the spinal cord, and run back as an independent system, giving off branches to the organ.

In the Mormyrus longipinnis the electric organs are on the tail. There are four of them, two on each side. In each organ there are about 150 membranous partitions running lengthwise of the fish, and placed $\frac{1}{360}$ of an inch apart, the spaces being filled by an albuminous fluid. (*Owen's Comp. Anat.*)

Electric organs are quite analogous to a voltaic pile in which electrical energy is accumulated in a state of tension. The nerves which liberate the discharge, are of the same class as the motor nerves which run to the muscles and liberate the energy which causes their contraction. Like those motor nerves, they are connected with the anterior tracts of the medulla oblongata or spinal cord, as the case may be. A voltaic pile, of the ternary type alluded to, may be made by alternate leaves of silver, zinc and woolen cloth arranged as in fig. 254. Zinc

being positive to silver, the top of each of the plates becomes positive, and the bottom negative. The top of the pile is therefore positive, and a wire connecting it with the bottom will conduct a current from the top to the bottom. The woolen cloths must have been saturated with dilute sulphuric acid (or a solution of sal-ammoniac in water). The creation of the current is due to the chemical action of the acid upon the metals. It has been proved that all chemical action develops electricity.

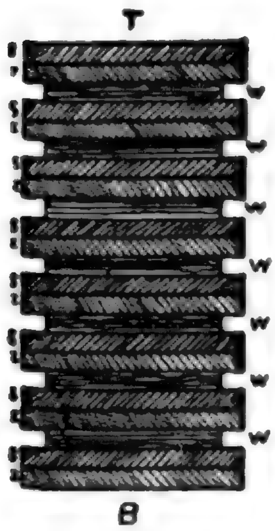


FIG. 254.—*Voltaic Pile.*
Z.—Zinc plates.
S.—Silver " [cloth.
W.—Moist woolen

Any irritating agent outside of the body coming into contact with the skin, sends, by way of the sensory nerve to the central ganglion either in the brain or spinal cord, a stimulation, which, deflected from the ganglia, returns to the electric organ along the motor nerves. If these nerves be cut in two and their cut ends be irritated, an electrical discharge takes place, the electrical organ, in this case, performing its function, as the muscle does under similar conditions. As before mentioned, these nerves are looped in their terminations the same as the nerves serving the muscles. The continued or repeated action of the organs soon exhausts them. The first shock of the Gymnotus is very formidable, and will easily kill any small animal, as a fish such as they use for food. Humboldt relates that horses are often killed by them, these animals being used by the South American Indians in fishing for the Gymnoti; the process being to compel the horses to receive the shocks of the fishes till they are exhausted, when they can be safely taken by the Indians. Rest and nourishment recuperate their functions, as in the case of muscles. The effect of strychnine is to cause involuntary discharges from the electric organs; at the same time it produces tetanus or violent involuntary contractions in the muscles.

The aponeurotic lamina and partitions which intersect the electric organs, appear to have the quasi insulating properties possessed by the neurilemma and sarcolemma sheaths of the nerve and muscle fibres; because each nerve fibre in the electric organ ministers to a definite tract, and when such nerve fibre is irritated (at its cut end), the electric discharge takes place only in so much of the organ as it reaches. If part of the motor nerves supplying the organ be cut, and a stimulus be applied to the skin of the animal, he is able to discharge the electricity of the part still in connection with the central ganglia, the brain or spinal cord, but not the part to which the severed nerves belong.

The shock or discharge from an electric fish is greater when two points are touched at once, and the farther apart the points are, the greater the shock. The most powerful shocks from the Gymnotus are when the head is grasped by one hand and the tail by the other. But

the shock is less as the hands touch points nearer together. The skin of the animal is no doubt a conductor, and the shock felt is the discharge from so much of the organ as communicates its electricity to the part of the skin between the points touched. The violence of the effect is thought to be due to the rapidity of the succession of the shocks. It is said that a single discharge of a Torpedo takes about one-fourth of a second, and it is composed of about 25 separate shocks. In the Torpedo, the top of the electric hexagonal prism, before described, that is, its dorsal end, is positive, while the ventral end is negative. In the Gymnotus, the head end is positive, the current being from head to tail. In Professor Faraday's experiments with the Gymnotus, "needles were converted into magnets; iodine was obtained by polar decomposition of iodide of potassium; and availing himself of this test, Faraday showed that any given part of the organ is negative to other parts before it, and positive to such as are behind it. Finally heat was evolved and the electric spark obtained." (*Owen*, *1-357.*)

There are so many points of analogy between the electric organs and the muscles, as to lead to the inference of a common origin for both. The electric organs in the Torpedo appear to be modified muscles, the prism, with its pile of flattened cells, being very like a muscle filament with its constituent flattened discs. If such flattened discs were fixed by their edges so that they could not contract under the electric stimulus, they would be constrained to discharge their electricity instead of turning it into work. They would thus become true electric organs. The electric cells of the other fishes seem to have undergone greater modification if we suppose them derived from ancient muscles, nevertheless their position in the animal strongly points to such derivation, and we can readily perceive that if their attachments did not mechanically restrain their contractility, their electricity instead of being discharged might be employed in the compression of the cells and the contraction of the organ.

It is observed that a strong discharge from the electrical organ is sometimes accompanied by muscular contraction. The Torpedo has one stout muscle, the business of which is to contract the electric organ itself. It has also been observed to retract the eyeball when delivering a discharge. There appears to be an intimate relation between the muscles and the electric organs. Obviously, the more the contraction of either of the organs, the less the electrical discharges. During the quiescence of the animal, the development of electricity goes on from the circulation of the blood and from the chemical reactions produced in it, and this electricity constantly accumulates in the electric organs as in an accumulator.

A large amount of electricity is generated in all animals, including

man, by the action of the muscles, the movement of the blood, processes of digestion, &c. A good deal of this production is incidental, and it is quietly conducted away and wasted, although there is still a considerable storage of electricity in all the tissues. If it could all be secured in accumulators, as it is in the electrical fishes, it might equal or surpass theirs in quantity. If a person wear non-conducting clothes, like silk and India rubber, the accumulations are often very considerable. There is a great difference in this accumulation in different people; often when certain people pull off their clothes, crackling sparks follow. The American Journal of Medical Sciences, Jan'y, 1838, mentions the case of a lady in whom electricity was so rapidly generated that whenever she was only slightly insulated by a carpet, or other feebly conducting medium, sparks would pass from her body to any object she happened to be near. Sometimes as many as four sparks a minute would pass from her finger to the stove, at a distance of 1½ inches. It was most abundantly produced at a temperature of 80°, and during tranquility of mind and social enjoyment. Experiments proved that it was generated in the body, and not by friction of the dress. It is said that in man the accumulation is generally positive, and in woman negative. People of an irritable disposition and sanguine temperament generate the greatest quantity. Cats have considerable storage capacity for electricity, and a perceptible shock may be given when it is suddenly let off. The same was once observed in regard to a mouse. *Todd Cyclo. Anat.*)

There are also *Electrical Plants*. One of these in Nicaragua is described as belonging to the phytolaccaceæ, or poke-weed family. When touched, it gives a shock like an electrical machine. It affects a magnetic needle at some distance, and when placed in the middle of the bush the needle takes a gyratory motion. The electrical power is slight during the night, and reaches its maximum at one or two o'clock p. m. It is greatly increased in stormy weather, and is much reduced in the dry season, the plant then remaining in a withered state. Another in India, also gives a shock on being handled, and it influences a magnetic needle at a distance of 20 feet. It is strongest about two o'clock, and weakest at night. Its power is greatly increased in a wind storm, but lost in rainy weather. It is probably the action of wind, weather and sun that develops electricity in these plants. It doubtless does in others also, but these must possess storage facilities like the electric animals. The aponeurosis in the electric animals, and the sarcolemma of muscles, and the neurilemma of nerves, are insulators of greater or less perfection, and probably the cells of the electrical plants are enclosed by some such membrane.

CHAPTER LVI.

NERVOUS SYSTEM.

Rhizopods, Amœbæ, &c., have no nervous system, the whole of their substance being contractile, and all possessing nervous properties diffused equally through it, and not differentiated from it. The Hydra, or fresh water polype, has the power of contracting its parts by very simple muscles lying between the exoderm and entoderm, or inner and outer skin layers, and it possesses sensibility or irritability, by means of which stimulations may cause the movement of all the parts at once, and its movements are correlated with each other, but yet there is no nervous system in the animal. The Sea Anemone, or Actinia, another cœlenterate animal, possesses a row of sensitive tentacles around the mouth, and its substance is very contractile, and also quite sensitive to touch and light irritations. Yet it has no nerves. During bright sunlight its tentacles are spread out like the petals of a flower, but if a cloud passes over they are folded up and retracted, and the mouth closed. Even the shadow of a hand will produce this effect. Its excretion of the waste products of its food materials is usually by way of the mouth—by which they entered; but if a piece of bone or shell happens to be a little unmanageable, it is pushed out through the side of the body wherever it is most handy, and the rent thus formed is speedily repaired. That animals so little differentiated as that, are still so sensitive to light and touch, and that the stimulations are able to affect all parts of the body, even those not directly stimulated, prove that the cells are themselves sensitive organs, and able like nerves to convey stimulation to other parts. Among the lowest orders in which a well defined nervous system is found, are the Echinoderms including the Encrinites, Starfishes, Medusæ, Sea urchins, Trepangs, &c. These animals, when adult, are constructed on the radiate or star plan, both muscles in the form of tentacles or arms, and the accompanying nerves radiating from a common center. In the lower orders of worms (Scolecida) we find the nervous system consisting of one or two ganglia, the general protoplasm of the body still possessing, in some degree, an undifferentiated conducting capability.

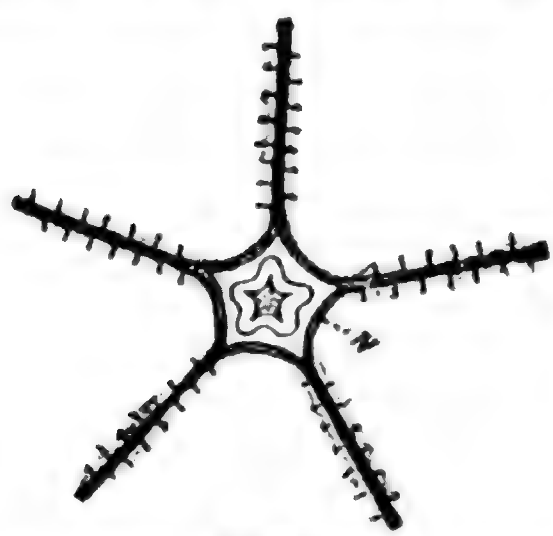


FIG. 255.

FIG. 255.—*Diagram of nervous system of Starfish.*
N.—Nerve ring which connects together the five ambulacral centers—or foot ganglions.

Tape worms, Liver Flukes, Planarians, Ribbon worms, Hair worms, Nematodes, &c., are examples of this stage of development. Among those worms which consist of a series of segments joined together one

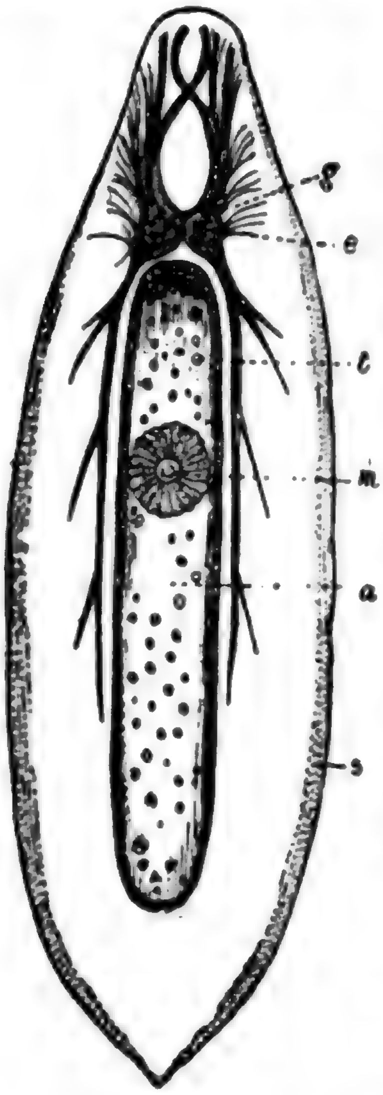


FIG. 256.

FIG. 256.—*A Turbellarian worm, Mesostomum Ehrenbergii.*
g.—Paired Ganglia connected by commissure.
e.—Eye spots or pigments.
t.—Nerve trunk.
m.—Mouth with pharynx.
a.—Alimentary canal.
s.—Skin covered with cilia.

FIG. 257.—*Brain and anterior part of the ganglionic chain of a Tube-worm—Serpula.*
G.—Cerebral ganglion (brain).
C.—Esophageal ring.
Ug.—Sub-esophageal ganglion.
e.—Nerves to the tentacles and mouth segment.
a.—Nerve chains with ganglions at each segment of the body.

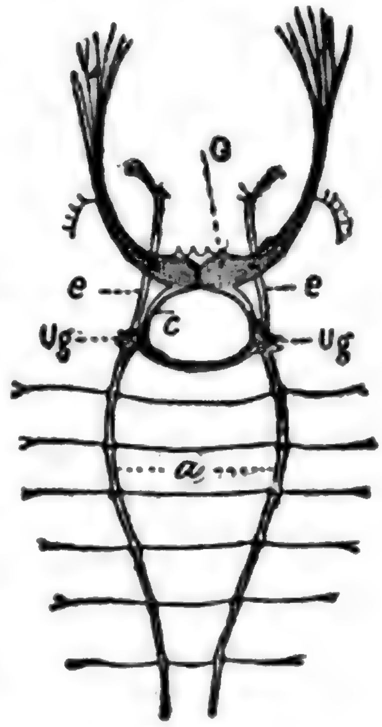


FIG. 257.

behind the other, and which are classified under the sub-kingdom *Annulosa*, we find a pair of nervous ganglia accompanying each one of the segments, and another encircling the neck and gullet, the whole joined to each other by fibres on each flank of the body, running from one end to the other. Thus, as the body is increased in the number of its parts, a harmony of movement and co-operation of action is secured among them by the balancing of the stimuli and their mutual reinforcement or partial elimination in the nervous ganglia.

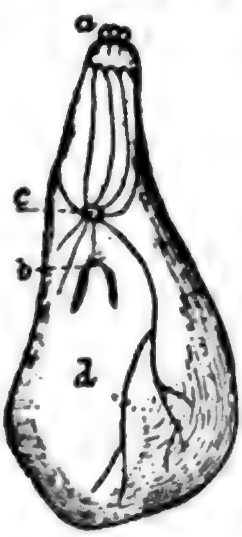


FIG. 258.

FIG. 258.—*Sea-Squirt (Ascidian).*
a.—Mouth. *b.*—Vent. *c.*—Nervous system.
d.—Muscular sac containing stomach, &c.

The ganglion of the Ascidian, fig. 258, when stimulated causes the contraction of the muscular bag which envelops its viscera and suddenly empties it, causing the "squirt," which gives the animal its common name. In Mollusks, generally, there are two masses of ganglionic matter, one above and the other below the esophagus. These are connected with each other to form a "throat ring," and from them nerve fibres radiate to the muscles, and such sense organs as they possess. Shell-fish like the pond Muscles, have a large ganglion and a sense organ in the fleshy projection called the foot, which is connected to the cerebral ganglion. The cephalopods (Cuttle fishes, &c.) have a central ganglion which answers to the brain, and possess also an independent ganglion in each

sucker. These last may act by reflex stimulation independently of the central ganglion, or they may be stimulated by the central ganglion, and so act in harmony with the rest of the body. The central ganglion is the nervous center of the special sense organs, sight, &c., so that when

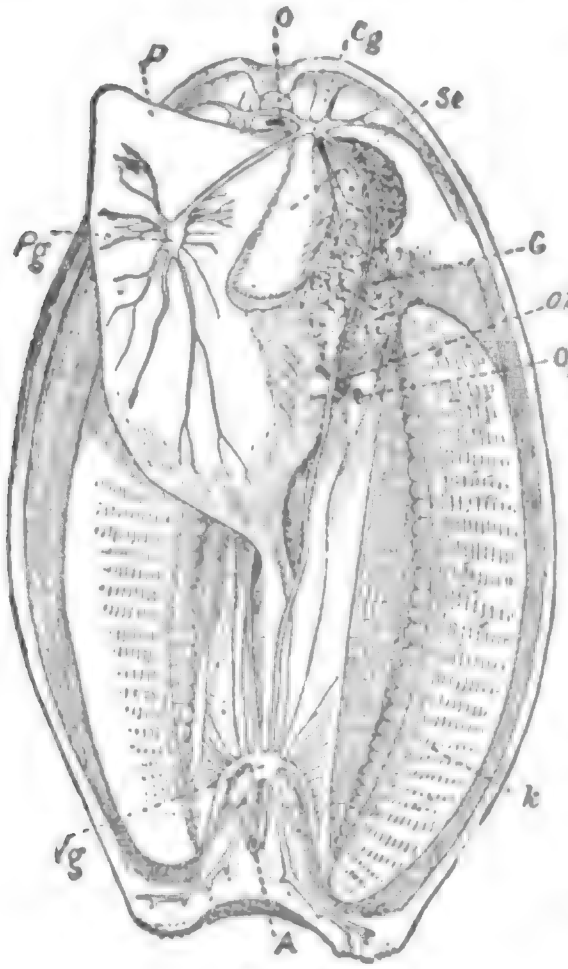


FIG. 259.

FIG. 259.—*Nervous system of Pond Muscle* (*Anodonta*).
O.—Mouth.
Cg.—Cerebral ganglion.
Se.—Labial palps—touch organs.
G.—Generative gland.
Ok.—External opening of kidney.
Og.—Opening of generative gland.
K.—Gills (large-paired organs).
A.—Anus.
Vg.—Splanchnic ganglion.
P.—Foot.
Pg.—Foot ganglion. (*After Keber.*)

the action is governed by it, the stimuli of sight, and other senses, overrule the stimulus of touch in the sucker. The suckers of the Cuttle fish will act by reflex stimulation when they are cut off from the rest of the body, it only being required to place them in contact with some object..

Among the articulates there is a central ganglion at the head end, the stim-

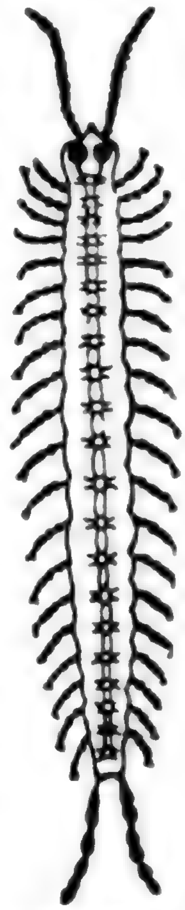


FIG. 260.

FIG. 260.—*Segmented worm, Centipede, showing nervous system.*

ulation of which is derived from the specialized senses, as in the Cephalopods, and there are likewise independent centers placed in each of the segments of the body. These segments, however, are not arranged around a center, but are placed in a row, one after the other. (Fig. 260.) The segmental ganglions are underneath the cavity of the stomach, one in each segment. Each segment usually supports two limbs, and the segmental ganglion is the medium of the reflex action which takes place in them, the central ganglion being the medium for starting action caused by stimulation from the special sense organs. The cephalic, or head ganglion, is placed above the mouth, thus indicating the position to be taken by the brain in the vertebrates, of which this ganglion is undoubtedly the forerunner. Its most important stimulating sense is, no doubt, the sense of sight. It is situated near the eyes, and in size usually bears a direct proportion to them. This ganglion is connected with the first segmental ganglion, which lies below it on the underside of the esophagus, or gullet, by a band of nervous matter on each side, so that the effect is to surround the esoph-

agus with a nervous ring. From this, bands of nerve fibres pass backward along the ventral side of the body, connecting the cephalic ganglion with each of the segments, by which the action of all may be controlled in harmony by the sight stimulus. If, while a Centipede is in motion, its head be cut off, the legs will continue to move, and so carry the body forward. But the guiding sense of sight being cut off with the head, there is no avoidance of objects which may happen to be in the way. The body runs against any obstacle, but if it be lower than itself it will mount over it and go on, but if it is too high, the body stops while the legs, not controlled by a guiding sense, will continue to move as if everything were all right. This motion is caused by the stimulus of the contact of the feet with the ground, and is the so-called reflex action. This action can be started in the limbs, when the animal is cut in two or the head cut off, by irritating the cut end of the nerves. If a middle section of the ventral nerve chain be removed while the Centipede is alive, the legs opposite that part become motionless, but those in front move in co-ordination with the head ganglion, while those back of the mutilation move by the touch stimulus, but not in harmony with those in front.

The Praying Mantis, an insect of the grasshopper kind, is another animal in which the effect of reflex stimuli can be readily observed. It has six legs, but the front pair are differentiated into a sort of claws, which are usually held aloft in an attitude which suggests its name, but is really an attitude of preying instead of praying, for thus it lies in wait. If the head of this animal be cut off it will still stand holding up its arms, and if any object be placed between them they will close upon it as when alive. If the segment to which these arms are attached, be cut off, the insect will continue to stand and resist attempts to overthrow it, and the wings will perform the same agitated movements as when the head is present. Moreover, if any object be placed within the arms attached to the abscinded segment, they will still grasp it as before.[1] These facts prove, as pointed out by Carpenter, that the ordinary movements of the insect are prompted by the reflex action of the ganglia of the ventral cord, such action being the continuance through the ganglia of the direct stimuli of touch. In life, the general movement of the body is *directed* by the stimuli through the eye, while the desire or impulse to move at all is internal, and comes from the state of the stomach, nerves from this quarter mingling their stimuli with those of sense in the optic ganglion, thus making this a real brain, albeit a very simple one.

The Gyrinus Dytiscus is a water beetle which slides about on the surface of summer streams. If one of these be beheaded and placed

[1] See Carpenter's Mental Physiology.

upon a *dry* surface it will remain motionless, but if placed on the water it will slide about as in life for half an hour. This indicates that the reflex machinery of this insect is differentiated to stimulus of a peculiar kind. The legs of the Centipede are stimulated by a dry surface, but this one requires a wet one. Other sorts of stimulation are possible often to the same organs, causing different sorts of reactions. Thus the presence of air in the lungs and windpipe stimulate the act of respiration, but the presence of some extraneous object, as dust or hairs, causes a tickling and coughing. So in the case of the headless Centipede, if his breathing pores, which lie along the side, be irritated by the vapor of ammonia, or something of that kind, the body will bend away as if to avoid it.

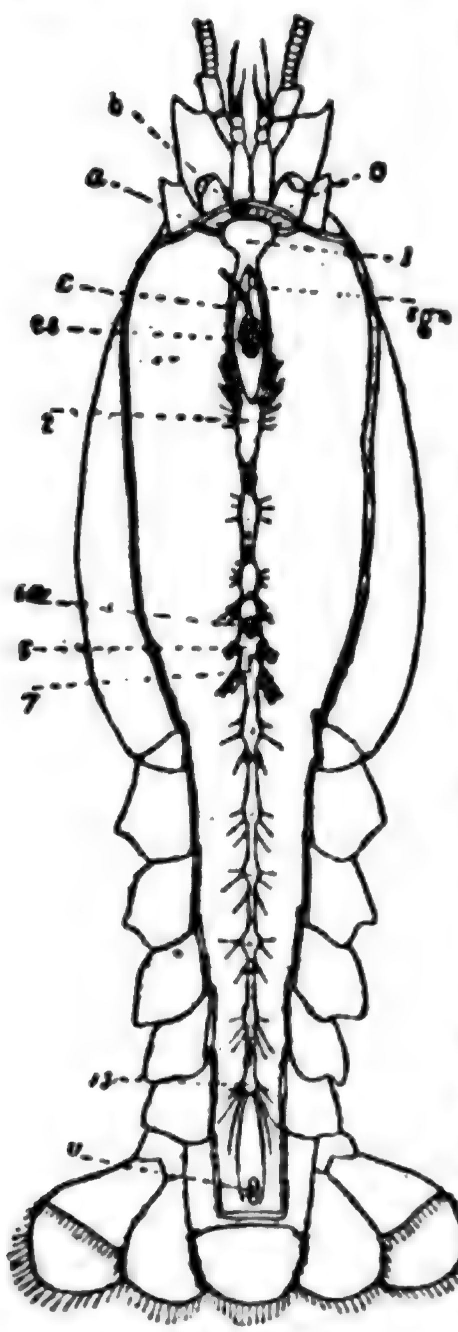


Fig. 261.

Fig. 261.—*Nervous system of Crawfish* (*Astacus fluviatilis.*) (*Huxley.*)
a.—Antennary nerve.
b.—Antennulary nerve.
c.—Circum-esophageal nerve.
es.—Esophagus in cross section.
o.—Optic nerve.
sgn.—Stomato gastric nerve.
sa.—Sternal artery in cross section.
v.—Vent.
1.—Supra esophageal ganglion.
2.—Infra " "
6.—5th Thoracic "
7.—Last " "
13.—Last abdominal "

We see in the foregoing examples, the action of external agencies, especially touch or contact stimulations, but also light, upon organisms, with the result of putting them into motion in various ways. There can be no mistaking the entirely reflex nature of the action of one of these animals with its head off, meaning by the term *reflex* that the stimulation, in the form of a motion of a body outside of the animal, sets up in the animal a polar current, which passes from the point of contact to a ganglion, and from thence to the muscles of the limbs, and causes them to contract and so give motion to the limbs. In other words, the headless organism is a machine in the same way that a water-wheel is, although a much more complicated one. But when the head is on, it is still not a whit less a machine, only its complexity is greatly increased.

The vertebrate body is constructed on the general plan of a worm, and, like it, is composed of a series of segments. These segments are arranged along a longitudinal axis called the spinal column. This is

composed of a series of short bones, called vertebræ, placed end to end. There is a hole in the posterior or dorsal part of each of the vertebræ, running parallel with the direction of the body, the effect of which, taken together, is a tube running the whole length of the spine. In this tube is the nervous trunk, called the spinal cord, which puts forth branch nerves in pairs, one pair for every vertebra. To the front or anterior sides of the vertebræ the ribs are attached. In the lower vertebrates, a pair of muscles goes with each vertebra, one on each side, and to each muscle a nerve is sent from the spinal cord. This is the case with the fishes.

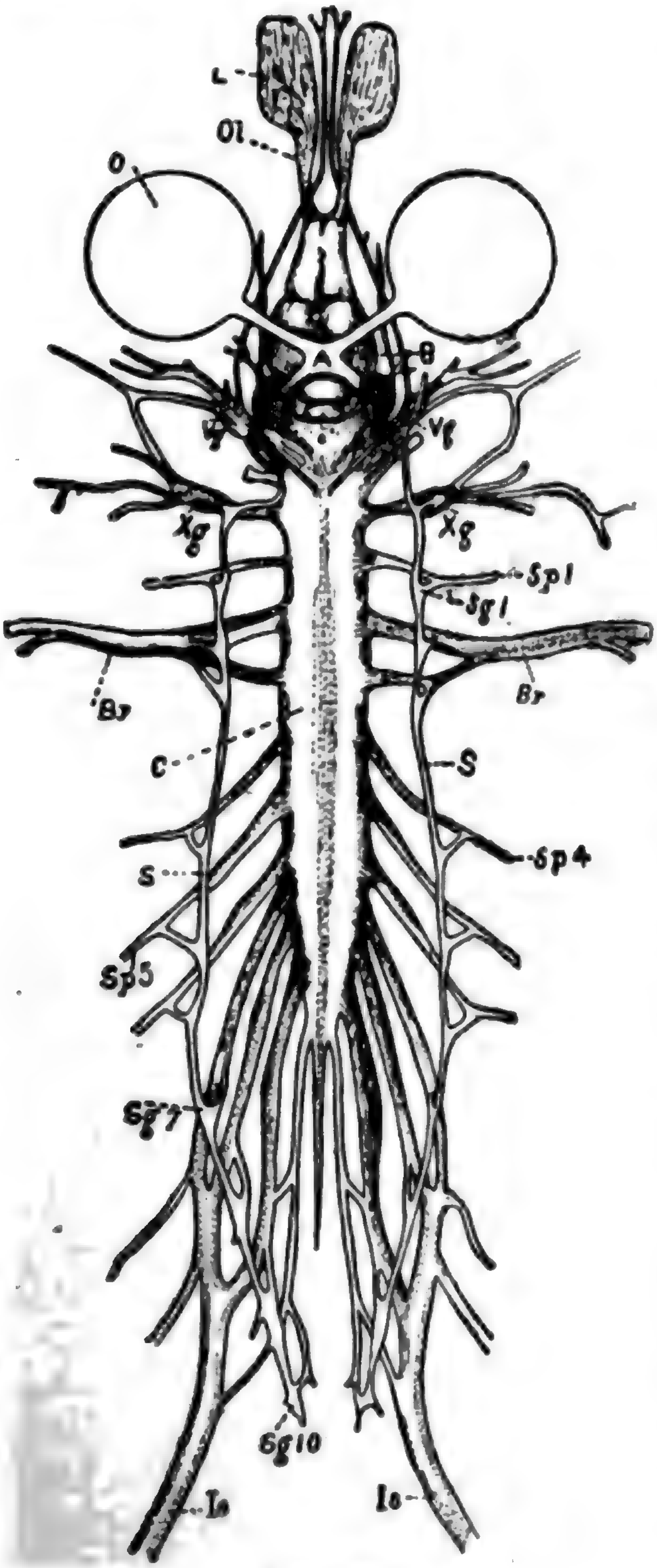


FIG. 262.

FIG. 262.—*Nervous System of Frog, underside.*
L.—Olfactory lobes.
Ol.—Olfactory nerves.
O.—Eye.
B.—Brain.
A.—Is placed on the crossing of the Optic Nerves.
Vg.—Ganglion of the 5th nerve.
Xg.—Ganglion of Vagus or 10th nerve.
Sp 1, Sp 4, &c.—Spinal nerves.
S.—*Great Sympathetic* nerves.
Sg 1, Sg 7, Sg 10, &c.—The ten ganglions of the sympathetic nerve.
C.—Spinal cord.
Br.—Brachial nerves (to the arms).
Is.—Ischial nerves (to the legs).
(*After Ecker.*)

After the development of limbs, the relationship between the vertebræ and the muscles became changed, the arrangement of the muscles gradually becoming such as best to accommodate the locomotive requirements of the animal. The relation of the nerves to the vertebræ, however, remains the same, and in all there are as many pairs of spinal nerves as there are vertebræ. In man, the number of each is thirty or thirty-one. The nerves are distributed to all the muscles of the body and limbs, and to every part of the skin. The nerve trunks leaving the spinal cord have two roots in the spinal cord called the posterior and anterior, so named from the

part of the cord in which they are situated. The fibres of these two roots come together and form a bundle, one on each side of the spinal cord. Before they join, however, the posterior fibres pass through a swelling or bunch of gray vesicular matter constituting the *ganglion* of the posterior root. After the junction of these two sets of nerves, they

FIG. 263.

FIG. 263.—*Cerebro-Spinal Axis.* (*Quain, after Bourgery.*)
F, T, O.—External right side of cerebrum, on the frontal, temporal and occipital lobes.
C.—Cerebellum.
P.—On the Pons Varolii. Between P and V is the large ganglion of the 5th nerve (trigeminum or trifacial).
mo.—Opposite and left of *Medulla Oblongata.*
ms & m. s.—Point to upper and lower extremities of spinal cord (spinal marrow).
ce.—On lowest lumbar vertebral spine marks the *cauda equina* (horse tail). The spinal cord at the bottom divides into a bush of fibres, called by this name.
CI.—First Cervical Nerve.
CVIII.—Eighth, or lowest, cervical nerve.
DI.—First dorsal nerve.
DXII.—Last dorsal nerve.
LI.—First lumbar nerve.
LV.—Last lumbar nerve.
SI.—First sacral nerve.
SV.—Fifth sacral nerve.
CoI.—Coccygeal nerve.
S.—Left sacral plexus.
The backbone is split down through the middle.

pass on out together towards the skin and muscles, subdividing into numerous threads as they go. It has been ascertained that the fibres which leave by the *posterior root* are *afferent or sensory* nerves, which connect with the skin and convey *to* the spinal cord the stimuli of touch. Those fibres which leave by the *anterior root* are *efferent nerves*, which convey the return, *or motor*, stimulus *to the muscles.* A part of the afferent fibres stop in the gray vesicles, which constitute a considerable part of the interior of the spinal cord, and so do a part of the motor fibres, so that some afferent stimuli pass into this gray matter by the nerves of sense, and, without stopping, pass on out as motor stimuli directly to the muscles, which thereupon contract. Actions thus simply and directly brought on, are called *reflex*, and involuntary. But a part of the afferent fibres, and of the motor fibres as well, do not connect with the gray vesicular matter in the spinal cord, but pass up the cord and do not connect with any gray matter till they reach the basal ganglia, or the cortex of the brain. Actions resulting from stimuli passing along these fibres, are apt to be modified by stimuli from other parts, perhaps delayed or counteracted. Such actions are said to be either *voluntary* or *sensori-motor.*

Thus a pair of nerves, one right and the other left, leaves the spinal

cord between each two of the vertebræ constituting the backbone. They are, in man, commonly reckoned as thirty in number; viz., eight pairs of cervical, twelve pairs of dorsal, five of lumbar and five sacral. Occasionally there are six sacral, when the whole number becomes thirty-one. Each pair of these nerves is in part motor and in part sensory. But the only sense of which they are the vehicle is the sense of touch, including that of pressure and heat, and they are often called the nerves of general sensibility. The motor part of the cervical nerves

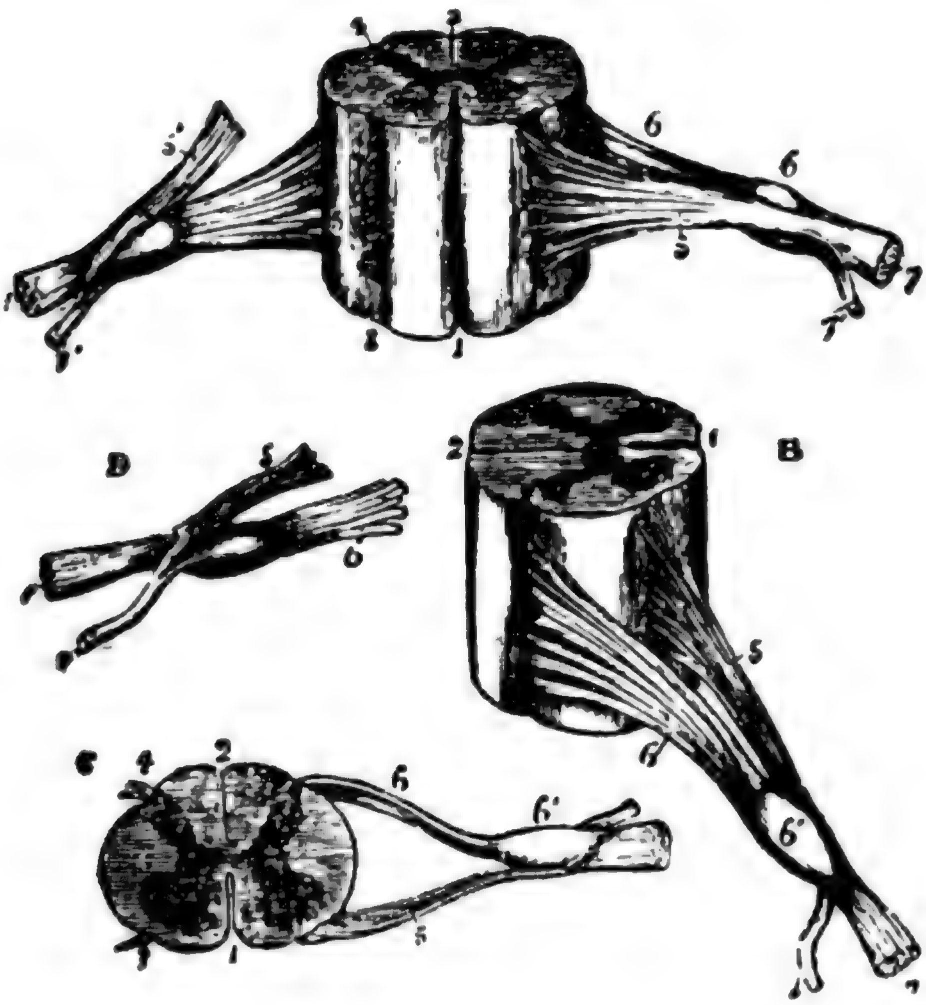


Fig. 264.—*A portion of the spinal cord from the cervical region, showing connections of the spinal nerves.*
A.—Front view. *B.*—Right side. *C.*—Cross-section.
D.—Underside of nerve-roots, and ganglion of posterior root. References same in all.
1.—The anterior median fissure.
2.— " posterior "
3.—Antero-lateral impression—place of connection of anterior roots. (shown too distinctly in fig.)
4.—Postero-lateral groove—connection of posterior, afferent roots.
5.—Anterior, efferent roots.
5'.—Anterior root divided and turned up (A).
6.—Posterior root, the fibres of which enter 6.
6'.—Ganglion of posterior root.
7.—The united or compound nerve.
7'.—The posterior primary branch, made up of fibres from both the anterior and posterior roots. (*After Allen Thompson.*)

reach the muscles of the neck and occiput, upper part of the chest and shoulder, arm and fingers; and a branch goes to the diaphragm; while the sensory portion of these nerves come from the skin of the neck, shoulders, arms, ears, &c. The motor portion of the first, second and third pairs of the dorsal nerves, mingle with the cervical in branches to the muscles of the arms and shoulders. The other pairs reach the mus-

cles of the ribs and abdomen, back and loins. The sensory portion of the dorsal nerves bring the sensation of touch from the skin of the abdomen, chest, loins and back. Of the lumbar nerves, the motor part connect with muscles in the abdomen, groin, thigh, leg, loins, sacrum, nates, and scrotum, while the sensory part receive the touch impressions of the skin of the same parts. Of the sacral nerves, the motor

FIG. 265.—*Brain and Spinal Cord of Human fœtus, 3 months.* (Kölliker.)
h.—Hemispheres of the Cerebrum.
m.—Midbrain—Corpora Quadrigemina.
c.—Cerebellum.
4.—Fourth Ventricle.
o.—Medulla Oblongata.
s.—Spinal cord.
b.—Its enlargement for the Arms.
l.— " " Legs, or Lumbar enlargement.

FIG. 265.

part serve the muscles on the external side of the leg, and part of the toes and the foot, part of the thigh, the organs of generation—uterus &c., and the bladder, nates, &c. The sensory part convey the touch stimuli from the skin corresponding to the muscular parts named. The relation between the spinal nerves, spinal cord and brain, are shown in figs. 262 & 263.

The nerves of all the senses, except touch, and some nerves of that sense, too, pass directly into the skull, and there connect with the great central nervous system of the body. These nerves of sense, together with others which pass out from the brain as motor nerves, constitute what are called the *Cranial* or *Cerebral Nerves.* In the vertebrates generally, including man, there are twelve pairs of them, as follows:

First pair are the olfactory nerves or lobes. They always, among the vertebrates, retain a connection with the hemispheres of the cerebrum, and often have a cavity in each which connects with the cavity of the corresponding hemisphere called the lateral ventricle. These olfactory lobes rest upon the ethmoid bone of the skull, through holes in the bottom of which the nerve fibres pass, connecting the olfactory lobes with the pituitary membrane of the nose. The lobes are to be regarded as parts of the brain, being real ganglia containing gray vesicular matter. This relationship is more obvious in the lower vertebrates in which the lobes are relatively more prominent, and the sense of smell relatively more highly developed. The nerves pass backward from the lobes to the Optic Thalamus, in which there are additional olfactory ganglia. The olfactory nerves are exclusively sensory, none of their fibres possessing any motor influence with any of the muscles.

The second pair are the optic nerves. These likewise start from lobes or ganglions, viz., the Corpora quadrigemina, in which each one has two roots, one in the natis and one in the testis. They pass forward from these ganglions by way of the optic thalamus, from which they receive large accessions of nerve fibres, which connect with the thalamus by two more roots on each side, thence along the base of the brain, each one of the pair converging toward its fellow. They cross each other, forming the *optic chiasm,* or *decussation,* in front of a grayish tubercle at the base of the brain, called the *Tuber cinereum.* After crossing, the nerves pass into the orbits of the eyes, and terminate upon the retina. They are sensory nerves, but are also closely connected with the third pair, through fibres of which reflex action is set up in the iris in the contraction of the pupil. Sneezing is also excited by reflex action of light, through connection with the fifth pair.

The third pair, the motores occulorum, move the majority of the muscles of the eye. They divide into two branches, the superior branch going to the rectus superior oculi, or superior straight muscle of the eyeball, and to the upper eyelid, and the inferior branch going to the lower and inner straight muscles, and the lesser oblique muscles of the eyeball. They are motor nerves, but have fibres which are sensory, receiving touch stimuli from the skin and sensitive surfaces about the eyeball. These nerves connect with the peduncles of the brain (crura cerebri) below the corpora albicantia, each one by two roots like

the spinal nerves. (Fig. 267, P III.) They leave the cranium through the sphenoidal fissures. (These consist of a hole in the skull on each side, opening from the brain through the sphenoidal bone into the upper back part of the orbit or eye cavity.)

The fourth pair are the Pathetici, or Pathetic nerves. This nerve moves the eyeball by its superior oblique muscle. It connects with the brain behind the corpora quadrigemina at the lateral parts of the valve of vieussens. It is both motor and sensory. It leaves the cranial cavity through the sphenoidal fissure.

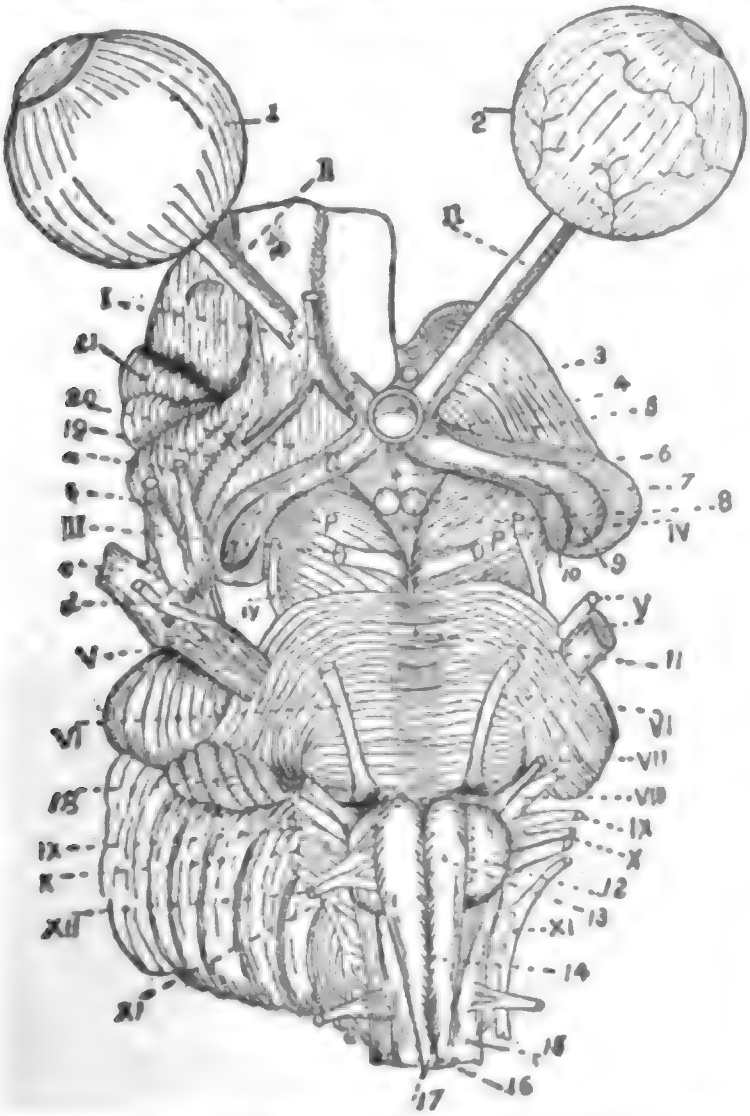


FIG. 266.—*Front view of Medulla Oblongata, Pons Varolii, &c., showing nerve roots. (From Quain, with additions.)*

On the right side, the convolutions of the central lobe, or Island of Reil, have been left; on the left, the cerebral lobes have all been removed, exposing the Optic Thalamus

I.—Olfactory nerve cut short.
II.—Optic "
III.—3d pair Occulo Motor.
IV.—4th pair Pathetic. (Muscles of eye.)
V.—5th Trigeminal.
d.—Motor root of the 5th nerve.
a, b, c.—Divisions of 5th nerve.
VI.—6th nerve (Abducentes) (muscle nerve of eye).
VII.—7th nerve, Portio Dura, Facial nerve.
VIII.—Auditory (Portio Mollis).
IX.—Glosso Pharyngeal.
X.—Par Vagum, or Pneumogastric.
XI.—Spinal Accessory of 10th nerve.
XII.—Hypoglossal, motor nerve of tongue.
1.—Globe of right eye, perfect.
2.—Globe of left eye, sclerotic and choroid coats removed.
3.—Pituitary body—Hypophysis.
4.—Optic Chiasm.
5.—Cut surface of left Optic Thalamus.
6.—Tuber cinereum and Infundibulum.
7.—Corpora Albicantia.
8.—Locus perforatus posticus.
9.—External Corpus Geniculatum.
10.—Internal " "
11.—Pons Varolii.
12.—Olivary body.
13.—Anterior pyramid.
14.—Decussation of pyramids.
15.—Lateral column of Spinal Cord.
16.—Anterior column " "
17.—Anterior median fissure of spinal cord.
18.—The flocculus.
19.—Fissure of Sylvius.
20.—Locus perforatus anticus.
21.—Island of Reil.
P.—Placed on Cerebral Peduncles.

The fifth pair are also called the Par Trigeminum (also Trifacial), from the fact that they divide into three branches each. They are both motor and sensory. The first branch is the Ophthalmic, which subdivides into three; viz., one, the lachrymal, to the lachrymal gland and upper eyelid; one to the forehead and upper eyelid; and the third to the eyelids, nasal fossæ and nose. The second branch is the Superior Maxillary, which has four subdivisions—one to the orbit of the eye; one to the last three molar teeth and gums; one to the front teeth and two lesser molars; and the fourth to the upper lip, cheek and nose. The third branch is the Inferior Maxillary, which has seven subdivisions, as follows: to the temporal muscle; to the masseter muscle, which moves the lower jaw; to the inner surface of the cheek; to the internal pterygoid muscle, which is also concerned in moving the lower jaw; to the *mucous membrane* of the tongue; to the teeth of the lower jaw and lower lip; and to the forehead and ear shell. This nerve connects with the brain by two roots, one motor and the other sensory, like the spinal nerves. The motor root connects with the posterior edge of the olivary tract of the medulla oblongata, and the sensory root runs back, or down between the olivary tract and restiform body to the sensory tract of the medulla. (See fig. 266.) Before joining the motor part of the nerve, *d*, the sensory parts, *a*, *b*, *c*, unite in a large nervous ganglion called the Gasserian ganglion. The part of this nerve which is distributed to the tongue, is the nerve of taste. The ophthalmic branch of this pair passes through the sphenoidal fissure. The superior maxillary branch leaves skull through the foramen rotundum.[1] The inferior maxillary branch passes through the foramen ovale.[2]

[1] [2] Holes in the sphenoid bone of the skull.

The sixth pair are the Abducentes. This nerve moves the rectus externus, or external straight muscle of the eyeball, which, by its contraction, rolls the eyeball outward. This nerve also supplies the nictitating membrane and the retractor bulbi, in those vertebrates which possess those parts. The root of this nerve is in the pyramidal tract of the medulla oblongata. (See fig. 266.) This nerve leaves the brain through the sphenoidal fissure.

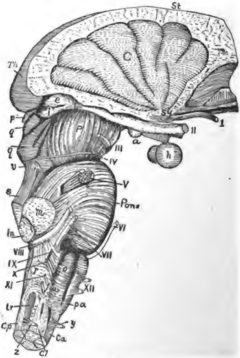


FIG. 267.

FIG. 267.—*Showing Island of Reil, Pons Varolii and Medulla Oblongata, with roots of the Encephalic or Cranial nerves. right side.*

St.—Upper surface of Corpus Striatum.
C.—Convolutions of the Island of Reil (all the cerebrum above this has been removed).
Th.—Back part of the Optic Thalamus.
e.—External Corpus Geniculatum.
i.—Internal " "
Sy.—Fissure of Sylvius in front of Isle of R.
p.—Pineal Gland.
q.—Corpora Quadrigemina.
v.—Valve of Vieussens—origin of 4th nerve.
a.—Right Corpus Albicans, with Infundibulum and tuber Cinereum in front.
h.—Pituitary gland.
P.—Cerebral Peduncles.
I.—Olfactory tract running past the fissure of Sylvius.

II.—Optic Nerve running back to *e* and *i*.
III to *XII.*—Encephalic Nerves. (See fig. 266.)
y and *z.*—Anterior and Posterior Roots 1st Cervical Nerve.
Pons.—Pons Varolii.
s, m, in.—Superior, Middle and Inferior Peduncles of the Cerebellum, cut short.
o.—Olivary body.
r.—Restiform body.
ar.—Arciform fibres.
tr.—Tubercle of Rolando.
pa.—Anterior pyramid.
ca, cp, cl.—Anterior. Posterior and Lateral columns of Spinal Cord.

(*Quain, after Allen Thompson.*)

Seventh pair is the Facial nerve. It is sometimes called the *portio dura* of the seventh pair. It supplies the superficial muscles and skin of the face, with branches to the pavilion of the ear, the hyoidean arch and the jaws. It connects with the brain by two roots, one to the olivary tract, and the other to the corpus restiforme. According to Carpenter, the portion that goes to the face is motor. The sensory fibres that are found with it are thought to be derived from the fifth pair and from the cervical nerves, with

both of which it anastomoses freely. It passes through the skull by way of the stylo mastoid foramen, a hole in the temporal bone of the skull.

Eighth pair is the Auditory, sometimes called the *portio mollis* of the seventh pair. t is purely sensory, conveying to the brain those agitations of the organs in the ear that go to make up the sensation of sound. In the ear it divides into two branches, one of which runs up the modiolus of the cochlea and distributes fibres to the four thousand arches of corti, and the other goes to the vestibule and distributes its terminal fibres to the semicircular canals, the auditory filaments of the crista acustica, and the otoliths. (Chapter 48.) This nerve connects with the brain by two roots, which embrace the restiform body, and originate in the floor and sides of the fourth ventricle and in the restiform body.

The ninth pair is the Glosso Pharyngeal. This nerve also originates in the restiform ganglion. It is sensori motor, but chiefly sensory, sending branches to the tongue, which convey thence both touch and taste sensations, and also controlling some of the muscles of that organ. It also has branches to the pharynx, and sensory touch fibres to the external canal of the ear. It leaves the brain by way of the posterior foramen lacerum, a hole at the junction between the occipital and temporal bones.

Tenth pair is the Pneumogastric, or Par Vagum. It is both sensory and motor. It arises from the restiform body, near the olivary body, and passes through the jugular foramen,[1] in the base of the skull, in company with the glosso pharyngeal and spinal accessory, the ninth and eleventh pairs. It runs down the neck, and alongside of the œsophagus through the diaphragm and into the stomach. Branches go to the pancreas, liver, gall-bladder, and duodenum, &c. Other branches go to the larynx, pharynx, heart, and lungs. It anastomoses in the neck with the spinal glosso pharyngeal, hypoglossal and great sympathetic nerves.

The eleventh pair is the spinal accessory. This nerve does not originate in the skull at all, but from the spinal cord about the fourth or fifth cervical vertebra, by fibres which issue from between the anterior and posterior roots of the cervical nerves. It runs up the cord and into the cranium through the great foramen, and leaves it in company with the par vagum and the glosso pharyngeal and the jugular vein, through the jugular foramen. It is called the accessory of the par vagum, because the two taken together form a pair resembling a pair of spinal nerves, the par vagum with its ganglion being considered the posterior, or afferent, and the accessory the anterior or motor. This nerve loses itself in the trapezius[2] muscle.

Twelfth pair. This is the Lingual or Hypoglossal nerve. It arises by ten or twelve very fine filaments from the grooves which separate the pyramidal from the olivary bodies, and some of the filaments are traced from the olivary ganglion. It passes from the cranium through the anterior condyloid foramen in the base of the occipital bone of the skull. It furnishes branches to several of the muscles of the neck, and the main stem gives its filaments to the muscles of the tongue and pharynx. It is a motor nerve.

The *Sympathetic System* is next to be mentioned. It consists essentially of two great cords, one on each side in front, or on the inferior side of the spinal column, and extending from the cranium to the coccyx. (See fig. 262.) These two cords start from a common point in the ganglion of Ribes, which lies near the corpus callosum in the middle of the brain, thence they diverge; each one passes with the carotid artery of its side, through the carotid canal in the temporal bone, and thence on down by the side of the spine through the neck, forming three neck ganglia, called the superior, the middle, or thyroid, and the inferior or vertebral ganglion; thence down the trunk, forming twelve thoracic ganglia, one for each of the dorsal vertebræ; thence through the loins, forming five lumbar ganglia; and below these three or four sacral ganglia; and at the coccyx, where the pair come together again, is formed a final small ganglion, the coccygeal. Thus the two homologous sides of the system are united at the two ends, head and tail.

From each of the ganglions above mentioned, a branch connects with the spinal nerves. There are also branches and some small ganglia connecting with the cranial nerves. There are three principal plexuses formed in connection with the sympathetic, which minister to the viscera of the chest and abdomen. These are the cardiac, solar, and hypogastric plexuses. The great cardiac plexus is situated opposite the third dorsal vertebra, at the point where the bronchial tubes branch off from the windpipe. It is formed by the union of the middle and inferior cardiac nerves, which, in turn, are formed by the convergence and union of fibres from the cervical ganglia. The great cardiac plexus also receives fibres from the first thoracic ganglion, the pneumogastric

[1] Also called the foramen lacerum posterius.
[2] A muscle at the posterior part of the neck and shoulder which elevates the shoulder, depresses it, or carries it back, according as one or other set of fibres is contracted.

and the hypoglossal nerves—tenth and twelfth pairs cranial nerves. The fibres passing from the great cardiac plexus, after being concerned in various complications of plexuses and ganglions, finally proceed to the heart and the great blood vessels, and follow the latter throughout the system in all their subdivisions and ramifications.

From the sixth, seventh, eighth and ninth, and sometimes the tenth, thoracic ganglia branches start out, descending inwards and uniting into a single trunk to form what is called the great splanchnic nerve. It enters the abdomen, passes behind the stomach, and divides into several branches which enter the semilunar ganglion. Thence numerous filaments emerge to form the great solar plexus, which is situated on the vertebral column, the aorta, and the pillars of the diaphragm. The nerves issuing from this plexus follow the aorta and all its branches, supply the liver, spleen, pancreas, kidneys, testes and ovaries, and the muscular walls of the stomach and intestines. The lesser splanchnic nerve, or renal nerve, is formed by two branches starting from the tenth and eleventh thoracic ganglia, passing downward and inward, and uniting at the twelfth dorsal vertebra into a single cord, which enters the abdomen through the diaphragm, then divides into two branches, one furnishing fibres to the kidneys through the renal plexus, and the other anastomosing with the great splanchnic nerve. The hypogastric plexus is formed by fibres from the sacral ganglia, and by branches from the lumbar and aortic plexuses. It sends off filaments which accompany the arteries that pass to the bladder, urethra, vagina, rectum, &c. It is situated near the rectum.

The sympathetic system is called by physiologists, the "nervous system of the automatic functions," and the "nervous system of organic life," in distinction from the cranio-spinal system, which is called the animal system. The vegetative, or automatic, functions are not under the control of the will, and go on in spite of it. All the organs concerned in these functions are reached by nerves from the sympathetic nerve centers, and many of them have no other supply of nerves. This is the case with the muscular coats of the small and large intestines, and the gland ducts connecting with them, also the muscular walls of the bladder, uterus, ureters, and fallopian tubes, also the greater part of the glandular apparatus. (Carpenter.) But the heart and stomach, the lachrymal, mammary, salivary and gastric glands are supplied by branches from the cerebro spinal system, in addition to those from the sympathetic system, which are distributed on the walls of their blood vessels.

The influence of the nerves of the animal system on the heart and glands, has already been noticed. This influence is simply a modifying influence, and has nothing to do with furnishing the motive power by which these organs are operated. It has been repeatedly pointed out that the *power* which causes the movements of the different parts of the organized body, is derived from the chemistry of the digestion of its food. The *regulation* of the movements, so that they may support instead of antagonize and neutralize each other, depends upon the influence of the motion of one part being communicated to that of another part, that is, motion in one part must accelerate or retard the motion of another with which it is in relation. This mutual influence of the separated movements upon each other, is seen in animals that have no nervous system, such as the hydra and actinia, and even the amœbæ. If a hydra be touched with a pin on one side, the effect is communicated at once to all parts. But the touching with the pin is

not the power which performs the contraction, it only sets it off. And likewise the passage of the stimulation from the point touched to other points at a distance, only touches off a force already there. The track traversed by the stimulation represents the track of a system of nerves not yet developed. When they are developed, as we find them in animals of higher organization, they are still merely the pathways of stimulations which do not furnish the chief power, but simply regulate its demonstrations. Now this regulation of the movement of an organ may come from any one of several sources, all of which together constitute its environment. The lungs may be made to move faster by a strong *emotion* and also by the *will*. In either case the path of the stimulation leads from the brain. They can also be caused to go faster after violent exertion or by the exhaustion of disease, in which cases the stimulation is from the viscera by way of the sympathetic system. Thus, whether the stimulation is from the animal part of the system or the vegetative; whether it is voluntary or involuntary; conscious or unconscious, it is the same, and consists of a nervous current along a differentiated route between two organs which have been developed in relation to, and more or less dependent upon, each other. It was early in animal development that a connection became established between the animal parts—locomotive, prehensile, &c., and the vegetative parts, stomach, &c. When the stomach is empty, the limbs and jaws must be subject to its stimulation and be set to work to fill it. When it is full, the stimulations from it to the animal organs cease, and these then cease to furnish supplies. The distinction often made between mental and physical stimulations is for convenience of study, and purely arbitrary. Regardless of its origin the stimulation is physical only. In a great many directions the influence of organs upon each other is carried by means of the sympathetic system alone, of the animal system alone, or by means of both, and it is to be observed that the nervous electricity is generated indifferently in both the animal and vegetative organs, and that it is conveyed indifferently from the nerves of one system to those of the other, backwards and forwards. There is no distinction in the character of the influence which one organ possesses toward another, no such distinction as mental and physical.

The effect of the numerous ganglions and plexuses into which the nerves run and convey their various currents, is to allow the modification of such currents by their mutual action and reaction in reinforcing or neutralizing, concentrating or dissipating, each other, &c. A current coming upon a single nerve from a single organ, may, in a ganglion, be split into two or more currents passing to as many different organs; or, coming from two or more, may be concentrated and continue from the ganglion as only one. It has been long supposed by physiologists that

the office of the ganglia on the roots of the spinal nerves, is to "cut off sensation." (Carpenter.) By this it is meant that these ganglia dissipate the stimulus of sensation. Thus, if one fibre of a bundle is the vehicle of a stimulus from a touch upon a part of the skin, it carries its stimulus uncommunicated till it reaches the ganglion on the posterior root. There it is communicated to the vesicular matter of the ganglion, and by it scattered to many, perhaps all, the fibres of the bundle as they proceed from the ganglion into the spinal cord. The same principle, says Carpenter, seems to apply to the motor fibres, because, when such fibres from the cerebro-spinal system pass through the sympathetic ganglia, they do not transmit motor impulses so rapidly or so surely as in the cases in which they are not so connected. Evidently the motor stimulus in emerging from the ganglion passes into so many fibres that its power over any one is reduced; but its influence is communicated wherever these subdivisions of it go, and tends to modify the action of other stimulations with which it mingles in any cell or ganglion. These vesicular bodies therefore elaborate the stimuli by these processes of dispersion and collection.

The movements involved in eating and assimilating food, are necessarily partly animal and partly vegetative functions, with essential co-operation between the two classes of actions. The muscular movements of placing the food in the mouth, and wagging the jaws in mastication, are under the control of the will, but mastication is attended with the involuntary flow of saliva, which is liberated from the salivary glands, and is an automatic resultant or accompaniment growing out of and consequent upon the voluntary animal movement of the jaws. But this flow of saliva may take place without the actual mastication of food, the thought of doing so being sufficient to produce the necessary stimulus. The propulsion of food through the pharynx and down the esophagus, is purely automatic, and is reflex from the stimulus excited by the presence of the food itself. It is not possible to perform the operation of swallowing unless there is something to swallow, the direct stimulus of a body in contact with the parts being essential. The movement cannot be initiated by thinking about it, nor by an exercise of the will, although the pharynx is connected with the cranio spinal nerve centers by means of the glosso pharyngeal nerve, and the esophagus is connected with the same by means of the vagus. These, with other nerve connections, however, serve to establish co-operation in the successive contraction of the parts concerned in the action of swallowing, which is therefore purely reflex. The passage of the stimulus through the cranial nerve centers may or may not arouse consciousness of the action going on, but at all events consciousness is not essential to the performance of the action.

When the food reaches the stomach it is in a position requiring the co-operation of the gastric juice which is discharged upon it from the gastric glands of the stomach. These glands are connected with the brain by the pneumogastric nerve, and when this nerve is stimulated there is an increase in the flow of the gastric fluid. Such stimulation takes place whenever food is taken into the stomach, and perhaps through the esophagus on its way down; but, as stated elsewhere, such stimulation may come at second hand, or indirectly, when there is no food to be digested, it being possible that the gastric glands may be stimulated by a "mental state," that is, by the action of associated parts of the brain. Thus, in the case of the hungry dogs, in which the flow of the gastric juice was provoked by a *sight* of food which they could not get, the stimulation took place in consequence of first a stimulation of the optic lobes of the brain, and next its propagation thence to the pneumogastric nerve, and through it to the stomach. The sensation of sight, and the aroused *memories* of gastric action, constitute the "mental state," which forms a part of the chain of stimulation in such case.

The above is a sample of the hundreds of co-operative reactions which take place in the complicated organic machine, in which the stimulation of every act is a resultant of influences that come from different parts of the body, some near and some remote. The differentiation which finally sets up one part of the organism to become more sensitive to the stimulation of external energy than the rest, has made some progress in the vegetable kingdom. We had some examples of it in chapter 54.

The *tops* of growing plants are sensitive to *light*, and the tips of the roots are sensitive to *pressure* and *moisture*. These two extremities are therefore sense organs, and they have means of nervous communication with other parts, which may be called motor organs. The bending of plants toward the light, which we often observe, is caused by the shortening of the cells on the illuminated side, and if a bending shoot be split down, that side will bend over still more, while the opposite side will tend to fly back. This bending will take place after the plant has its growth, and is not, therefore, in all cases, a growing process. This bending is produced by the blue and violet rays. Leaves also twist on their stalks in order to present the green surface to the light. The uppermost part or tip of (some) seedling plants, is alone sensitive to light, and it transmits an influence to the lower part, causing it to bend. If, therefore, the upper part be wholly protected from light, the lower part may be exposed for hours to it, and yet does not become in the least bent, although this would have occurred quickly if the upper part had been excited by light. As the shortening of the cells, spoken of above, that causes the bending of a stem, takes place at some distance from the point which receives the stimulation of the light, there must be a

means of communication, and the passage of an influence from the one to the other.

The ends of twining stems, such as hop, morning-glory and bean, sweep around any object suitable for them to cling to, making a turn every few hours. The touch stimulus is the naturally exciting cause of this, and its effects are at, and a little above, the point of contact. Touch stimuli also cause the twining of the tendrils of climbing plants. But in the case of some varieties of the Virginia creeper, the touch organ takes the form of a disc or button, and sticks like a sucker to the side of a house or tree. Movements of these plants are also complicated by the influence of light, the tendrils traveling much faster in the part of the revolution in which they are moving toward the light. The tendency to twine is, to a certain extent, inherited by some of these plants, because they, in some cases, perform their revolutions before they reach a proper support.

Darwin names 86 genera, belonging to many different families of plants, which go to sleep at night. This they do by some particular disposition of the leaves or leaflets, some turning them down in a vertical position, others raising them upright. The Sensitive Plant turns one on top of another. This movement is, to some extent, hereditary. The Sensitive Plant closes up some time before sunset, and opens again before it is fully light. Yet without doubt the habit was originally developed by the action of light. There are some species which sleep after a bright day, but not if the day has been dark. Still, in most of them, the habits are fixed, so that the preparation for night occurs without regard to the change in the amount of light. Many of these plants, especially the sensitive plant, will, upon being touched or agitated, fold up their leaves as in sleep. These movements of the leaflets are due to a change which takes place in their little stalks or petioles, and evidently a stimulus passes through the cells of the leaflet from the point where it is agitated to the petiole. The petioles of the plants which make these movements are differentiated in a peculiar manner, as shown in fig. 268. This differentiated tract is called a *pulvinus* (ridge). The cells in this tract are smaller than the ordinary cells of the leaf and the rest of the petiole, their development being arrested before they are grown, and they possess little or no chlorophyl. The more sensitive the plant, the greater the differentiation of the cells, and the less chlorophyl do they have. The effect of stimulation is to expand or contract alternately, first one side and then another of the pulvinus, and to cause an accession of sap and a turgescence and erection of the tissues; a process which appears to be analogous to the action of animal erectile tissues. But the point to be especially noted is the transfer, through the cells of the leaf, of the nervous stimulation necessary to set up this action. We have, in fact, a nervous current without nerves.

Equally remarkable is the action of the rootlets of growing plants. The radicle of the pea in pushing its way into the ground does not penetrate directly but bores down spirally, a process which is brought about by the growth of cells progressively around the point of the advancing root. The tips of the rootlets are very sensitive, and when one encounters a little stronger pressure on one side than the other, it transmits a stimulation upward to a part of the root some little way above. At this place an expansion of one side, or contraction of the other, bends the radicle so as to move the tip away from the obstruction which causes the pressure. When the stimulating agent is moisture, however, the tip is made to turn toward it by the proper bending of the stem above. The expansion of the cells is accompanied, perhaps caused, by an extra amount of sap forced into them, and this results from the nervous stimulation sent up from the tip of the root. Experiments made by sprouting and growing beans in a moist air, suspended above the ground, showed that the radicle always turned toward the earth. If, after a radicle had grown to some length, the bean were fastened so as to place the radicle in a horizontal position, as it continued to grow it would take a downward direction, making a right angle turn. So that this tip is not only sensitive to pressure and moisture, but to the direction *down*. This last faculty must have some big name, so it is called *geotropism*. The sensitiveness of the tip of the root, is confined to a length of root not more than $\frac{1}{20}$ of an inch.

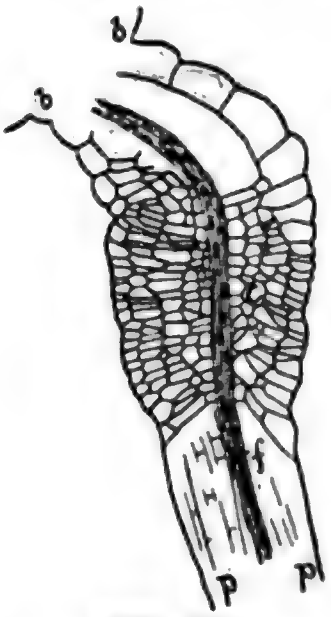


FIG. 268.

FIG. 268.—*Pulvinus of Oxalis Rosea* (a wood sorrel).
A longitudinal section of the petiole or leaf stalk of a cotyledon or first formed leaf.
p.—The Petiole.
f.—Bundle of fibres and vessels.
b.—Beginning of the blade of the cotyledon.
c.—The cells constituting the Pulvinus or joint, the motor organ of the leaf. (*Darwin.*)

FIG. 269.

FIG. 269.—Extremity of root of growing Plantlet, greatly enlarged.
B.—Its " Brains" at the tip.

When that much was cut off, the sensitiveness of the root and its disposition to bend upon being stimulated, was destroyed, and was not restored for about 24 hours. The complete regeneration of the tip, in the case of beans, requires about three days. The tips were cut off 29 horizontally extended radicles of common beans (in a moist air), and they did not bend toward the earth for 22 to 23 hours, whilst unmutilated radicles bowed downwards in eight or nine hours. (Darwin, Movement of Plants.)

Darwin says: "It is hardly an exaggeration to say that the Tip of the Radicle thus endowed, and having the power of directing the movements of the adjoining parts, acts like the *brain* of one of the

lower animals; the brain being seated within the anterior end of the body, receiving impressions from the sense organs and directing the several movements."

CHAPTER LVII.

ANATOMY OF THE BRAIN.

The spinal cord, or medulla spinalis, is reckoned to end at the entrance of the skull—the foramen magnum. The fibres of which it is

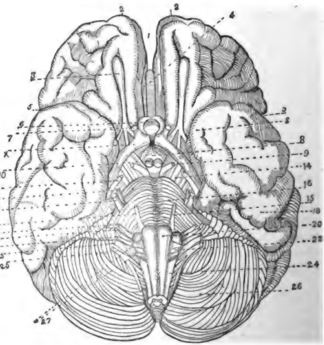


FIG. 270.—Base of the human brain.

1.—Great longitudinal fissure.
2.—Frontal lobes of the Cerebrum.
3.—Olfactory bulb.
4.—Corpus Callosum.
5.—Fissure of Sylvius.
6.—Pituitary Gland.
7.—Optic nerve.
X.—Optic chiasm.
8.—Tuber cinereum.
9.—Third nerve—Motor oculi.
10.—Corpora Albicantia, or mammillary tubercles.
11.—Fourth nerve—Pathetic.
12.—Fifth nerve—Trifacial, motor root.
13.— " " " sensory root.
14.—Crus cerebri—Peduncle.
15.—Sixth nerve—Abducens.
16.—Pons Varolii.
17.—Seventh nerve—Facial.
18.—Middle lobe of the Cerebrum.
19.—Eighth nerve—Auditory.
20.—Anterior Pyramid. Crossed fibres in lower part.
21.—Ninth nerve—Glosso Pharyngeal.
22.—Olivary body.
23.—Tenth nerve—Pneumogastric.
24.—Lateral tract of the Medulla Oblongata.
25.—Eleventh nerve—Spinal-accessory.
26.—Cerebellum.
27.—Twelfth nerve—Hypoglossal.
S.—Subiculum cornu ammonis (inner anterior aspect of uncinate gyrus.)

composed keep right on, however, into the cranium without break, so that this limit at the great foramen is purely artificial. Nevertheless, soon after its entrance into the cranium, the body of the cord undergoes modifications and new arrangement of parts, which justifies a change in its name, and it is called the *medulla oblongata.* The front, or anterior, part of the medulla oblongata rests upon the base or front part of the occipital bone, which forms part of the base of the skull. Like the spinal cord, the medulla oblongata is divided into lateral halves by a front and a dorsal groove, which correspond with, and are continuations of the front and dorsal grooves of the cord. There are, consequently, parts corresponding with the anterior, posterior and lateral columns of the spinal cord, to which, however, new names are given. On the anterior side of the medulla oblongata, and about midway of its length, a large proportion of the nerve fibres of the column on the left of the anterior groove or fissure, cross over the groove to the right side, and those on the right cross to the left. (Fig. 266.) These anterior columns are called the anterior pyramids, and this crossing of fibres is the decussation of the anterior pyramids. The fibres of the pyramids spread out as they go forward, so that the base of the pyramid is toward the head end of the body. On each side of the anterior pyramids is an ovoid eminence called, from its shape, the olive or olivary body. Seen from the posterior side, the posterior columns of the medulla oblongata appear to subdivide, the fibres on each side next the fissure forming a distinct bundle, which, spreading out towards the forward end, become the posterior pyramids. What is left of these posterior columns, together with the fibres of the lateral columns, constitute what are called the restiform bodies (corpora restiforme), which occupy the sides and posterior parts of the medulla oblongata, between the posterior pyramids and the olivary bodies. There are some fibres from the anterior pyramids which pass around the inferior or hind ends of the olivary bodies toward the restiform bodies, and accompany them forward toward the cerebellum. These are called arciform fibres. (Fig. 267.) There are other arciform fibres which leave the olivary bodies themselves and make for the same destination. The functions of the different parts of the medulla oblongata correspond largely with the functions of the corresponding parts of the spinal cord with which they communicate. The posterior pyramids and the restiform bodies, being chiefly derived from the posterior half of the spinal cord, are chiefly sensory as it is, while the anterior pyramids and the fibres of the olivary bodies, derived mostly from anterior half of the spinal cord, are chiefly motor. These characters follow the fibres through the medulla into the ganglia beyond it, as will be seen.

There is a body of gray vesicular or brain matter connected with each

of the bodies of the medulla oblongata, except the anterior pyramids. These gray bodies, like the gray matter of the spinal cord, are situated in the interior and covered by the white, fibrous substance, but are not diffused through the body of the organ. The ganglion in the center of each olivary body is called the olivary ganglion, or sometimes the *corpus dentatum.* This is the nucleus of the glosso pharyngeal nerve, and also the lingual branch of the fifth nerve. The ganglion in the restiform body is the ganglion of the tenth pair (vagus, or pneumogastric), and also of some of the roots of the glosso pharyngeal. This is probably the sensory ganglion for the visceral parts of the body. The ganglion belonging to the posterior pyramids, is situated on the floor of the fourth ventricle, a cavity formed by the widening of the posterior fissure of the medulla oblongata. This ganglion belongs to the auditory nerve. In man, and the higher mammals, it is small, having been superseded by other ganglia in the optic thalamus and cerebrum. But in some of the fishes this is a large and distinct center like the optic lobes. The

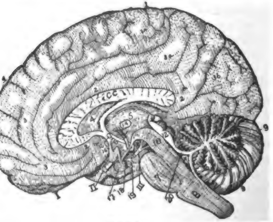


FIG. 271.

FIG. 271.—*Section through Brain, showing mesial surface of right hemisphere, and position of central and basal ganglia.* (*After Allen Thompson, slightly altered.*)

1, 2, 3, 3a, 3b.—Are on cerebral convolutions.
4.—Fifth ventricle, same shape as Septum Lucidum.
5.—Third ventricle, and position of Right Optic Thalamus.
6.—Position of the buried right anterior pillar of Fornix.
7.—Section of Pons Varolii.
8.—Medulla Oblongata.
9.—Cerebellum.
10.—Crus Cerebri.
11.—In fourth ventricle under and between the peduncles of the cerebellum. The white band to the right is the posterior cerebellar peduncle.
12.—Corpora Quadrigemina.
13.—Pineal gland, its right peduncle reaching forward. To the left of the figure is the posterior commissure.
14.—Soft commissure.
15.—Anterior commissure, and position of Corpus Striatum.
16.—Lamina Cinerea.
17.—Section of Pituitary body—its two lobes.
18.—Tuber Cinereum.
19.—Twist in the anterior pillar of the fornix which forms the Corpus Albicans, or mammillary tubercle.
20.—Valve of Vieussens seen edgewise. It *covers* the right anterior peduncle of the cerebellum.

position of this ganglion is the same as that occupied by the ear in many of the invertebrates. That part of the restiform body which is not concerned in the composition of the peduncles of the cerebrum—crura cerebri—is turned backwards at right angles from the medulla oblongata at the pons varolii, and accompanies the fibres of the pons into the cerebellum, and becomes the posterior peduncle of the cerebellum.

There is a heavy band of transverse fibres which passes across the anterior face of the medulla oblongata just above the olivary bodies, which is called the *pons varolii.* (See figs. 266, 267, 272.) This band passes on each side around the upper part of the medulla, and its fibres are lost on either side in the lobes of the cerebellum. The pons varolii is the forward boundary of the medulla oblongata, but the fibres which enter into the structure of the medulla pass on and contribute to the formation of other organs. The anterior pyramids are entirely of fibrous structure, and pass forward behind the pons varolii, some of the fibres passing between those of the pons. Beyond the pons they continue in a large diverging bundle on each side forward toward the cerebral lobes, and above or anterior to the pons they are denominated the *peduncles of the brain*, or the *crura cerebri.* The peduncles are not, however, made up exclusively of the fibres from the anterior pyramids which are efferent or motor, but on their posterior part there are afferent or sensory fibres. These are, in part, derived from the posterior pyramids, and, in part, from the restiform bodies. The posterior pyramids as they pass forward diverge from each other, and at the same time approach the anterior pyramids, and thus form a layer of sensory fibres on the dorsal side of the crura cerebri. In this movement they are likewise accompanied by a portion of the fibres from the restiform bodies. As the posterior pyramids pass through the pons varolii, a portion of their fibres decussate, crossing from each side to the other.

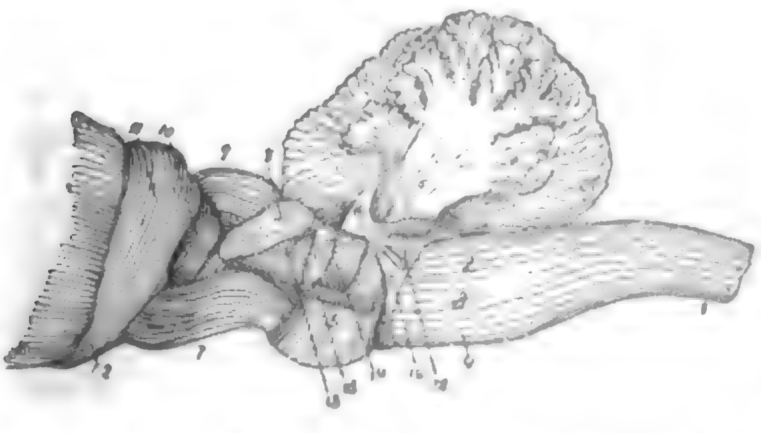


FIG. 272.—*Side view of part of the Brain of the Horse.*
1.—Medulla Oblongata.
2.—Restiform body.
3.—Position of Olivary body.
4.— " anterior pyramid.
5.—On the Pons Varolii.
6.—Middle peduncle of the cerebellum, that part of the figure above (6) is the cerebellum.
7.—Peduncle of the Cerebrum, or *crus cerebri.*
8.—Testis, the rear bulb of the *Corpora Quadrigemina, or optic lobes.*
9.—Natis, the front bulb of the same.
10.—Corpus geniculatum internum of the *optic thalamus.*
11.—Corpus geniculatum externum of the same.
12.—Optic nerve.
13.—Fourth nerve, pathetic, resting on the band of Reil.
14.—Sensory root of the fifth nerve, trigeminum.
15.—Motor root of the same.
16.—Facial nerve, seventh pair.
17.—Auditory nerve, eighth pair.

This sensory layer on the back of the crus cerebri, is called the *tegmentum* (cover). The anterior or motor portion is called the foot of the crus. Beneath the corpora quadrigemina the gray matter of the

crus is much darker than that of any other part of the brain, and it is here called the locus niger, or black spot. Fibres from this place proceed to the fornix, the great inferior longitudinal commissure of the brain. After passing the corpora quadrigemina, the crura cerebri split up and disappear. A part of the fibres, both motor and sensory, pass into the lenticular nucleus, or anterior end of the *corpus striatum* (fig. 348, 349, 350, 354); a part of the sensory (but none of the motor) tracts pass into the optic thalamus; and the remaining motor and sensory tracts expand into two thin bodies on the outside of and embracing the optic thalami. These are called the *internal capsules.* Beneath the optic thalamus and lying between it and the internal capsule, is a group of cells apparently sustaining to the capsule the same relation which the *locus niger* does to the foot of the crus. This group of cells is called the *sub thalamic* region. The internal capsule, besides the main body of fibres from the crus cerebri, receives fibres from this *sub thalamic* region and from the thalamus itself. Of the internal capsule thus made up, the anterior two-thirds consists of motor elements, and the posterior one-third of sensory tracts embracing paths of sensation, including tactile sensation, muscular sense, pressure, &c., fibres which come up the spinal cord. The fibres, after passing through the internal capsule, are joined by others from the sub thalamic region and from the thalamus, and the whole form what is called the *corona radiata*, a radiating crown which sends its diverging fibres to every part of the cortex of the cerebrum.

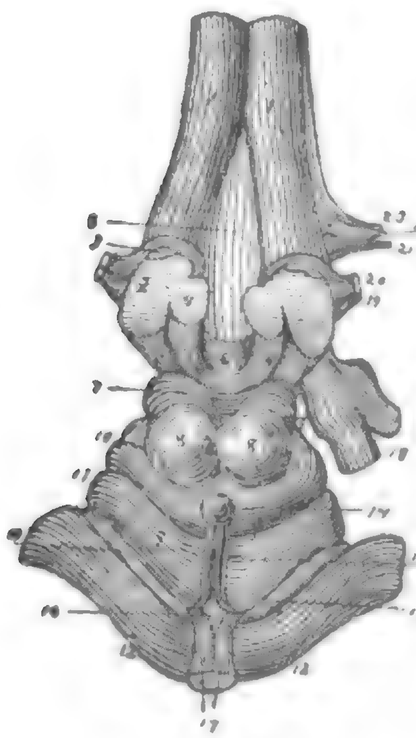


FIG. 273.

FIG. 273.—*Top view of Medulla and Basal ganglia of the Horse.*

1.—Upper end of the fig. shows the restiform bodies on the posterior part of the medulla oblongata.
2.—Section of the pons varolii, which becomes the middle peduncle of the cerebellum (cerebellum is removed).
3.—Section of the posterior peduncle of the cerebellum, which is a continuation of the restiform fibres.
4.—Anterior peduncle of cerebellum.
5.—Floor of the fourth ventricle.
6.—Valve of vieussens, stretching across between the two anterior peduncles.
7, 7.—The rear bulbs of quadrigemina—testes.
8, 8.—The anterior bulbs of " nates.
9, 9.—On the optic thalami.
10.—Corpus geniculatum internum of the thalamus.
11.— " " externum " "
12.—Corpus striatum.
13.—Tenia semicircularis.
14.—Pineal gland.
15.—Its peduncle.
16.—Foramen of Munro.
17.—Anterior pillars of the Fornix.
18.—Sensory root of fifth nerve, trigeminum or trifacial.
19.—Facial nerve (7th).
20.—Auditory nerve (8th).
21.—Glosso pharyngeal.
22.—Pneumogastric or vagus nerve (10th).
23.—Spinal accessory (11th).

The peduncles, or crura cerebri, are separated from each other by a fissure corresponding with the anterior fissure of the medulla oblongata. It is called the interpeduncular fissure. The surface of the inner sides of the peduncles is very much perforated by numerous blood vessels

connected with the overlying pia mater. This has been termed the substantia perforata. It, in part, forms the base of the corpus striatum.

Just in front of the cerebellum, and on top of the cerebral peduncles, are the *corpora quadrigemina.* These consist of two bulbs of nervous matter on each side. The hinder one is the smaller. It has a core of gray vesicular matter covered by a coat of white substance. It is called the testis. Joining it in front is the other, called the natis. An oblique band of nerve fibre passes from the testis outwardly past the natis, and connects with the corpus geniculatum internum of the optic thalamus. The nates are larger than the testes, and composed of gray matter almost entirely, the white coat being thin. In the lower part of each one of the nates is a vesicular nucleus called the *red nucleus* or *nucleus tegmentum.* These nuclei are the forward terminations of the anterior peduncles of the cerebellum, which pass from the cerebellum under the testes, and enter these red nuclei. The part of the lateral external face

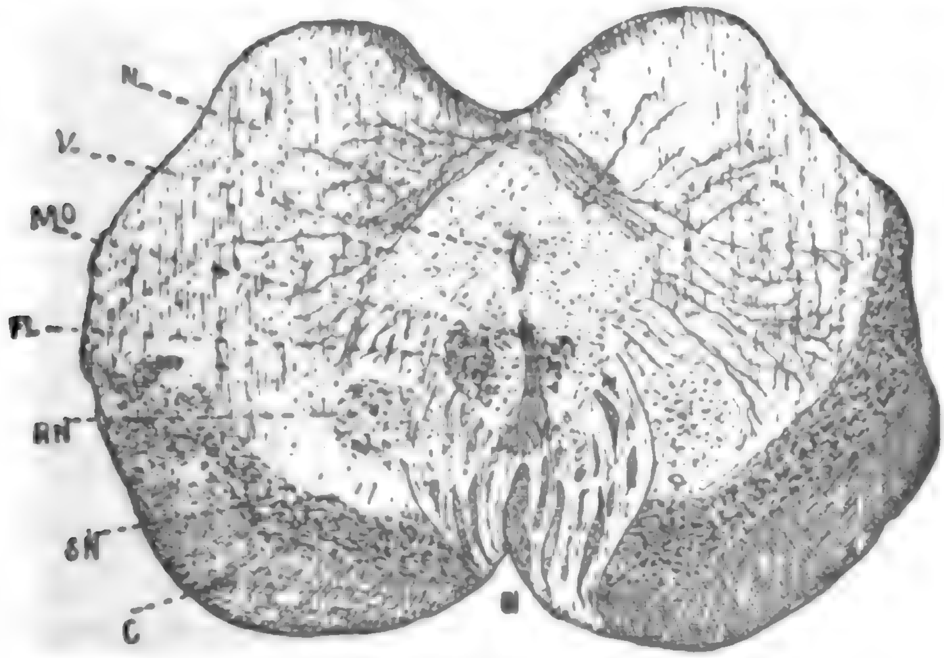


FIG. 274.

FIG. 274.—*Frontal cross section of Corpora Quadrigemina of monkey, at the origin of third nerves.* (*Ferrier, after Bevan Lewis.*)

C.—Crusta or foot of crus cerebri.
FL.—Posterior longitudinal fasciculus.
MO.—Nucleus of motor oculi, or 3rd nerve.
N.—Nates.
RN.—Red Nucleus or Nucleus Tegmenti.
SN.—Substantia nigra, or locus niger—(black place).
V.—Aqueduct of sylvius surrounded by central gray substance.
III.—Roots of the 3rd nerve (motor oculi).

of the cerebral peduncle which lies beneath the testis, forms a triangular tract called the band of Reil. On the median line, under the corpora quadrigemina and above and between the peduncles, is a longitudinal opening leading from the fourth ventricle in the rear, to the third ventricle in front. It is called the aqueduct of sylvius.

The corpora quadrigemina are the ganglions of sight. The nervous tissue composing them is intimately connected and confounded with the substance of the inner sides of the crura or peduncles; such connection giving chiefly sensory stimuli. But besides this, the testes have connection with the *motor tract* by means of fibres to the olivary bodies, which

pass from the posterior side of the crura to the front side, as they pass through the pons varolii on the road from the testes to the olivary bodies.

The Optic Thalami (which have been mentioned) lie on the posterior or motor tracts of the cerebral peduncles immediately in front of the corpora quadrigemina and separated from them by a curved transverse groove. They are intimately connected with the tegmentum or sensory part of the crura cerebri. They are much larger than the corpora quadrigemina and are composed entirely of gray vesicular matter. There are two projections from the thalami on each side ; the forward one is the more prominent and is called the corpus geniculatum *externum.* The hind one does not project so far and is called the corpus geniculatum *internum.* This is connected backward by a band with the testis. The anterior somewhat rounded end of the Optic Thalamus is called the anterior tubercle, and the posterior end is the *pulvinar.* Under and between the two sides of the Optic Thalami is a cavity called the third ventricle. At its rear end this communicates with the aqueduct of sylvius, and at its front end is an opening called the foramen of Munro (also called anterior common foramen), which opens above the corpora striata into the lateral ventricles. A band of gray medullary matter that joins the two lobes of the thalami over the top of the third ventricle is called the middle commissure of the brain. At the hind end of the optic thalami is another transverse band, composed of white fibres which are lost in the body of the thalamus on each side. This is the posterior commissure of the brain. It forms the hind terminus of the third ventricle.

Corpora Striata. These bodies form the anterior part of the floor of the cavities called the *lateral ventricles*, the optic thalami occupying the middle part, while the cornu ammonis or hippocampus major passing over the optic thalamus fills the reflected or descending prong or cornu of the ventricle, to be further described hereafter. In shape the front end of the corpus striatum is spherical or bulging, while in the rear it runs tapering backwards and partly enclosing the sides of the optic thalamus with a prolongation of medullary matter which terminates at the deflection of the descending cornu of the lateral ventricle. Each of the corpora striata is separated from the optic thalamus by a groove in which lies a narrow medullary strip called the Tænia Semicircularis, or Tenia Striata. This band running towards the front connects with the Fornix at the foramen of Munro. At the same point the peduncles of the Pineal Gland unite with the Fornix.

The posterior ends of the corpora striata practically form the floor of cavities called the lateral ventricles, of which the cerebral hemispheres are the roof. They are connected with the *motor* or anterior fibres of the crura cerebri, as the optic thalami are with the *sensory* fibres. These two ganglionic bodies, therefore, occupy the same relative position to

each other as that between the front and posterior sides of the spinal cord. The corpus striatum is a reddish gray mass of flabby consistence more friable, and easily lacerated by congestions, than the optic thalamus, a fact which explains why it is that paralysis of motor power results from disease oftener than paralysis of sensation. The ends of the motor or anterior and lateral fibres of the crura cerebri, penetrate the corpus striatum in all directions in the shape of serpentine filaments. These antero-lateral bundles of nerve fibres are finally terminated in the yellow nucleus which lies in the central and lower or anterior part of the corpus striatum and is in part within the lateral ventricle, and in part is pressed out under the edge of the overhanging cerebral hemisphere. This yellow nucleus is of firmer consistence than the rest and is peculiarly striated. A large part of the lateral fibres which terminate in the yellow nucleus are connected backwards with the pednucles of the cerebellum, and according to Luys are afferent to the corpus striatum, bringing to it the condensed co-ordinated stimuli of the cerebellum. The gray matter of corpus striatum is composed of an infinite number of large polygonal cells with many prolongations in various directions, their size being similar to that of the large cells in the cortex of the cerebrum, to be described. They have the same general character as all other cells, having the nucleus and nucleolus and the branching prolongations which rapidly taper away and mix with the similar prolongations of their neighbors, the result being a dense mass of delicate network. There are also great numbers of small cells, especially in the yellow nucleus. They have a large nucleus of yellowish color, and they resemble the small cells which are scattered among the large ones in the cerebral cortex, and they are also in substance like the small cells in the cerebellum. They are possessed of a very fine fringe of little roots which are lost in the network formed by the larger cells. In addition to these components are the capillaries of the blood vessels which penetrate among the nerve fibres from below upward. The efferent fibres from the corpus striatum originate in the plexuses of cells in the gray mass of the body where they are indistinguishably mixed up with the afferent fibres from the crura cerebri cerebellum and optic thalamus. From there they pass downward in bundles isolated from each other, which are collected into masses and form the anterior columns of the crura cerebri or peduncles of the brain. These are the motor fibres, the afferent fibres from the cerebellum being connected with the posterior columns of the crura cerebri. The motor isolated bundles are distributed to the different ganglions of the motor nerves which connect with the medulla oblongata and spinal cord, dropping out from the general mass of the spinal axis one at a time, as the root connections of the several nerve trunks are reached. Only the posterior end of the corpus striatum is

visible in the ventricle of the hemisphere. It is the smaller tapering end and is called the ***nucleus caudatus*** or ***intra-ventricular ganglion.*** The anterior end of the corpus striatum lies outside of the ventricle under the hemisphere of the cerebrum. It is rounding and bulging toward the latero-anterior part. It is the principal part and as regards motor function the final part of the striatum. It is called the ***nucleus lenticularis***, or extra ventricular ganglion. Whatever motor connections the nucleus caudatus possesses, they are by way of the lenticularis. The latter has its direct connections with the foot of the *crus* (motor) and with the tegmentum (sensory). Outside of the anterior parts of the corpus striatum, viz., the nucleus lenticularis, is a thin plate of gray matter called the *claustrum*, and outside of this and lying within the fissure of sylvius is a lobule of convoluted gray matter called by various names, as the *Lobule* of the *Corpus Striatum*, the *Intermediate Lobule*, the *Lobule* of the *fissure* of *Sylvius*, and the *Insula* or *Island* of *Reil.* This lobule and the adjoining convolutions of the cerebrum on the margin of the fissure of sylvius, are concerned in the faculty of motor speech. The Island of Reil cannot be seen from the outside of the brain.

It is now desirable to go back and describe other organs connected with the medulla oblongata, and other parts of the encephalic isthmus.

The Cerebellum. This is a large mass which lies on top of the fourth ventricle, and in man constitutes $\frac{1}{8}$ to $\frac{1}{6}$ of the whole brain. In man and the mammals it consists of three lobes. The middle one, which is called the vermis, occupies the cavity of the fourth ventricle. In the lower animals, the vermis is much more prominent than in man, and in birds it constitutes almost the whole of the cerebellum. It resembles the dorsal view of a silk worm rolled up, with its extremities concealed beneath. The middle part of the vermis is, in the higher animals, broken up and ill defined, but the front and rear are easily seen, and are called, respectively, the anterior and posterior vermiform process. To the anterior vermiform process is attached the posterior border of the valve of vieussens, or valve of the brain, which forms the front boundary of the fourth ventricle and the hind boundary of the aqueduct of sylvius. The posterior vermiform process is attached to the restiform bodies by a membrane of triangular shape, which covers the hind end of the fourth ventricle. The lateral lobes of the cerebellum are like two halves of an irregularly-shaped sphere. They are covered with sulci and fissures running in many windings, and penetrating to various depths into their substance. Unlike the medulla oblongata and spinal cord, the gray vesicular matter of the cerebellum is on the outside. It is in two layers, separated by a thin layer of white matter. Both layers contain nerve cells and other small, rounded bodies, the whole constituting the cortex. This cortex covers the convolutions, and

follows the fissures and sulci into the interior parts of the lobes. When a lobe is cut open, the section of these ramifications appear like the branches of a bush, to which is given the name *arbor vitæ.*

There are no ventricles or cavities in the cerebellum of man, the interior of the lobes being composed of white fibrous matter. In the interior of each, however, imbedded in the white fibres, is a body of gray vesicular matter, called the corpus dentatum, or the rhomboideum. The white fibrous matter is continuous with the terminations of the fibres which compose three several bundles on each side, which, taken collectively, are called the peduncles of the cerebellum (or crura cerebelli). The largest of these bundles is from the pons varolii, the fibres of which turn up around the sides of the superior end of the medulla oblongata and take a posterior direction into the lobes of the cerebellum. These are called the middle peduncles. The posterior peduncles are composed of a part of the restiform columns, which detaches itself from the rest and bends backward at right angles to the medulla oblongata, and, attaching itself to the middle peduncle, accompanies it into the lobes of the cerebellum. The anterior peduncle consists of a bundle of fibres which originates in the cerebellar lobes and proceeds downward along the inner border of the middle peduncle, then forward towards the corpora quadrigemina. A part of the fibres seem to connect with the testes, the rest to proceed beneath these bodies in company with the band of Reil, and so to connect with the lateral part of the crura cerebri. This peduncle thus furnishes the communication between the cerebellum and cerebrum.

The connection between the pyramids and the peduncles of the cerebellum, is a crossed one, the left peduncle being related to the right pyramid, and the right peduncle to the left pyramid. It is doubtful if there is any direct connection between the cerebellar peduncles and the pyramids; the connection being formed through the cells in the pons—the *nucleus pontis.*

The *valve of vieussens* has been mentioned. It is a thin sheet of medullary matter, which forms the separation of the fourth ventricle from the aqueduct of sylvius. By its posterior edge it joins the anterior vermiform process of the cerebellum. Its anterior edge is joined to the rear of the testes. Its lateral edges join the right and left anterior peduncles of the cerebellum, thereby forming a commissure between these peduncles. Its fibres are mostly tranverse, reaching across from one peduncle to the other, but these are also mixed with longitudinal fibres.

The *pineal gland* is a small, conical-shaped mass, of soft consistence and reddish color, without any cavity. In its substance, in a little heap at the bottom, are generally found a lot of calcareous granulations. It is single and median, and of varying size in different tribes of animals,

and different individuals of the same tribe. In the horse it is placed over the hind end of the third ventricle, above the corpora thalami, between the middle and the posterior commissures. In man it covers a cavity called the common posterior foramen, which communicates downward into the third ventricle. Its base is formed by a circular lamella, or sheet of medullary matter, which is attached by its edges to the circumference of the cavity. From the lamella, in front, proceed two narrow white bands. These pass along towards the front in the fissure separating the two thalami, one of the bands being attached to each of the thalami. When they reach the foramen of munro they become attached to the anterior pillars of the fornix, to be hereafter described.

From the lower floor of the front end of the third ventricle there is a diverticulum of the ventricular cavity which forms the cavity of a small gray bulb called the *Tuber Cinereum.* It is single and median. Underneath and in front of the tuber cinereum is a funnel-shaped tube, its base, or wide end, attached to the tuber cinereum, while its apex, or small end, is attached to another bulb, the *hypophysis* or *pituitary gland.* This tube is called the infundibulum, or funnel. It is composed of gray matter, and is very fragile. The hollow of the tuber cinereum is continued into it and ends there as a blind sac. The *pituitary gland*, which is attached to the little end of the infundibulum, is composed of matter almost amorphous, which, in the front part is yellow, and in the hind part, brown. It is circular in shape, flattened above and below, and differs in size in different subjects. It contains no cavity. It is at the very bottom of the brain, and rests in a hollow of the sphenoid bone called the sella turcica, or Turk's saddle. The front part is called the anterior lobe, and the rear is the posterior. The former is the larger and is concave behind, partly embracing the latter. In fishes, and other low vertebrates, the cells of the walls of the pituitary body develop into nerve cells and fibres, and it is joined to the rest of the brain as a part of it, and is called the lobe of the infundibulum. Its function as part of the active brain, appears to have backslid in man and the higher vertebrates.

The Cerebrum. This is the largest part of the brain in man and the higher vertebrates. It is divided into two hemispheres by a deep fissure, which cleaves the ends and the top from front to rear. Into this fissure dips a fold of the dura mater, which, from its shape, is called the falx or sickle. It is accompanied by blood vessels. The posterior end of the hemispheres in man and the apes, rests upon the cerebellum, from which it is separated by an expansion of the dura mater, called the tentorium. Each hemisphere is divided into three lobes, the anterior, middle and posterior. The anterior is separated from the middle lobe by a deep, transverse cleft called the fissure of sylvius. In it is lodged

the middle cerebral artery. There is usually in adults no well marked separation between the middle and posterior lobes. In the fœtus, however, there is a distinct furrow between them. In the horse, ox, and other mammals, the posterior lobe is rudimentary or wanting; the middle, or mastoid lobe extending back far enough to merely cover the anterior bulbs of the corpora quadrigemina, the nates, while the cerebellum covers the testes. But in man and the apes the posterior lobes extend to the rear, so as to cover not only the corpora quadrigemina but the cerebellum itself.

The two hemispheres are connected together by a great band of transverse white fibres, called the *corpus callosum.* This band extends far enough back to be above the corpora quadrigemina, and far enough forward to cover the corpora striata. The fibres pass under the falx cerebri in crossing from side to side, and turn up into the body of each hemisphere, mingle with the fibres which constitute the central parts of the hemispheres, and, without doubt, connect with the gray cells which make up the cortex. On top of the corpus callosum, in the middle, are two longitudinal bands of white medullary matter running from the front to the hind end. They are called the chordæ longitudinalis. The corpus callosum is the great commissure of the hemispheres.

At its anterior extremity the corpus callosum bends downward forming a knee or genu. The posterior end also bends under, the fibres becoming mixed up with those of the body of the fornix. This bend is called the splenium. The fibres from the different parts of the corpus callosum have been given different names. Those which leave the anterior end and curve forwards and inwards to accommodate the anterior lobe are the Forceps anterior. Those which leave the posterior end and curve backwards to supply the posterior lobe are the Forceps. While those which pass directly outward from the same into the middle lobes are the Tapetum.

Underneath the corpus callosum are the cavities called the lateral ventricles. These cavities are close together in front, where they are separated by the partition called the septum lucidum, but they diverge from each other toward the rear. In the bottom of the front ends of the cavities lie the corpora striata. The end of each cavity is continued forward to a point called the anterior cornu or horn. In nearly all the vertebrates there is a canal opening from the extremity of the anterior cornu into the olfactory lobe. In man this is closed. The backward projection of the lateral ventricle is outward from the center, then one prong passes downward toward the base of the brain with a final turn to the front ending in the substance of the brain by a blind sac or point. This is called the descending or middle cornu in man and the apes, and its location is in the second or middle lobe. In the higher mammals,

horse, ox, &c., this cornu is the posterior cornu and its termination is in the base of the mastoid lobe, which is their second and last lobe. In man and the apes there is another prong of the lateral ventricle, which points backward and downward into the posterior lobe. This is called the posterior cornu. The descending cornu is nearly filled by a process of brain matter, called from its shape the cornu ammonis or the horn of Jupiter Ammon. It is also called the *Hippocampus Major.* It is connected at its superior extremity with a convolution of the brain in the anterior lobe, called the gyrus fornicatus, the inner face of the temporal lobe which lies upon the corpus callosum. From its connection with this body, the Hippocampus Major passes backward in the lateral ventricle, connects with its fellow of the opposite side above the optic thalamus. From this point each one passes outward and downward into the descending cornu of its side. The central part of this process of the brain is gray matter. But it is covered outside by a layer of white which is furnished as a prolongation from the fornix, to be described. On the concave or anterior border of the Hippocampus Major in the descending cornu, this white layer forms into a thin, rather wide, delicate band, called the corpus fimbriatum or tænia Hippocampus. Opposite the lower or anterior end of the descending cornu, the cortex of the temporal lobe is thickened up into an almond shaped tubercle which is called the *nucleus amygdale.*

Fornix (Arch). This is the name given to a great longitudinal commissure which, by its various connections, unites together from front to rear, those parts of the brain situated underneath the corpus callosum. It consists essentially of a flat body of longitudinal fibres lying against the under side of the corpus callosum on the median line, the extensions of which, before and behind, constitute its anterior and posterior pillars. Where it curves down and away from the corpus callosum in front there is left a wedge shaped space between the two. This space is divided in the middle by a double vertical curtain of nervous matter from the under and front parts of the anterior lobes, called the *septum lucidum*, the upper edge of which is attached to the corpus callosum, and the lower to the fornix, the spaces thus separated being the anterior ends of the lateral ventricles.

The structure of the fornix will be best understood by accompanying the description with a diagram, fig. 275. Beginning with the fibres, the union of which constitute the anterior pillars, we find a bundle on each side coming from the interior of the optic thalamus (5) and turning down between the crura cerebri till they reach the bottom of the crura. There these bundles make a sudden turn and twist upwards and forwards towards the front, forming, by such twist, the two small bulbs called the corpora albicantia (or mammillary tubercles, 19). A few

fibres (22) are received at this point from the locus niger of the crura cerebri (10). The band then runs forward toward the anterior commissure (15), which apparently, but not really, connects the two corpora striata, before reaching which it receives fibres from the base of the brain (2). Then it bends upward against the anterior commissure with which it is connected, and forms what are called the anterior columns,

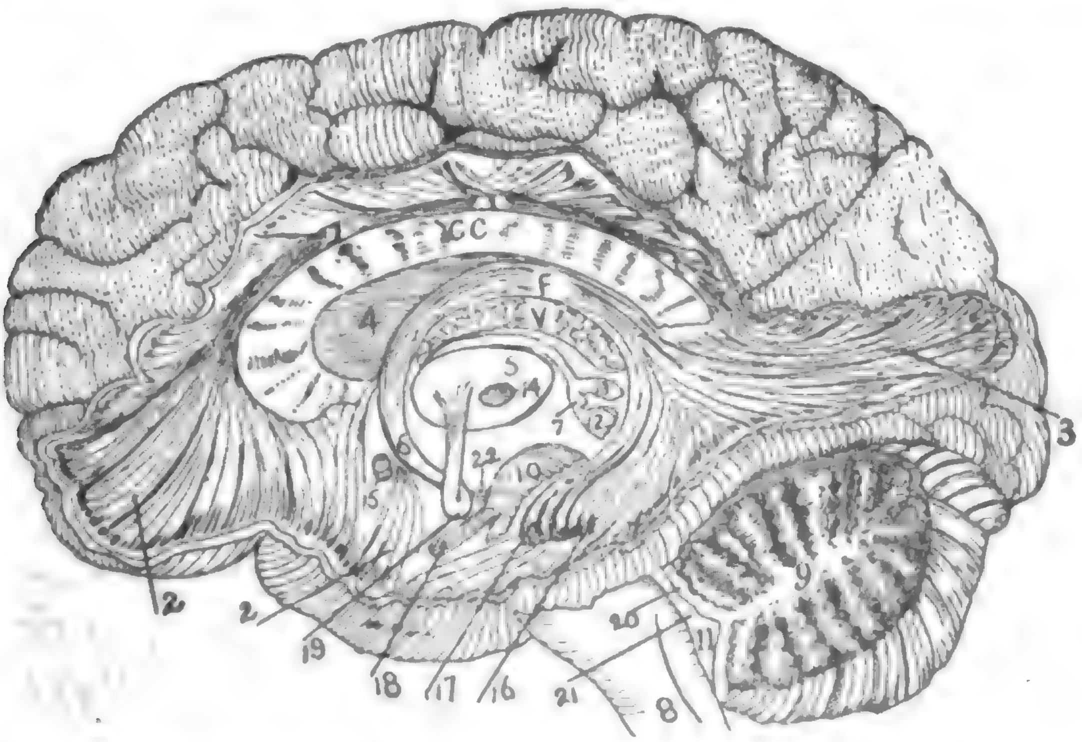


Fig. 275.—*Section of Brain to show the relations of the Fornix—partly diagramatic.*

C C.—Corpus callosum.
F.—Body of the Fornix.
V.—Velum interpositum.
1.—Chordæ longitudinales—longitudinal fibres above the corpus callosum.
2 2.—Nerve fibres from the chordæ, corpus callosum and fornix to the front and base of brain.
3.—Same to posterior lobe.
4.—Septum lucidum in same position as 5th ventricle.
5.—Optic Thalamus.
6.—Anterior pillar of Fornix.
7.—Posterior commissure.
8.—Medulla oblongata broken off at top.
9.—Cerebellum.
10.—Inner end of crus cerebri.
11.—Fourth ventricle.
12.—One of the corpora quadrigemina.
13.—Pineal gland.
14.—Middle or soft commissure.
15.—Anterior commissure.
16.—Fibres from Fornix covering hippocampus major.
17.—Fibres from Fornix covering the pes, or foot, of the hippocampus major.
18.—Third nerve.
19.—Corpus Albicans.
20.—Valve of Vieussens in profile.
21.—Aqueduct of Sylvius.
22.—Fibres from the Crus to the Fornix

or pillars of the fornix (6). Thence it bends upward and backward over the foramen of munro. Here it receives the tenia semicircularis and the peduncles of the pineal gland. Then receiving on its outside the insertion of the inferior edge of the septum lucidum (4), the fornix passes over the inner ends of the cornua ammonis and the optic thalami, and flattening itself against the underside of the corpus callosum it forms what is called the body of the fornix (F). A part of its fibres on the median line become confounded with the body of the corpus callosum. At the back part of the brain the fornix again divides into the posterior pillars, one leaf from each side passing down into the descending cornu in company with the hippocampus major, or cornu ammonis, and forming over it a layer of white medullary matter. On the concave border of each descending cornu, this white substance is thickened

up into a sort of band, the corpus fimbriatum or tænia hippocampi, the so-called posterior pillar. Other fibres pass backwards into the posterior lobes (3), the posterior cornu, and hippocampus minor, while still others, crossing over the hippocampus major (16) and its "pes" (17), connect with the middle lobe. The fornix is white throughout, except a grayish tint at its summit.

The brain is enclosed by three membranes called the pia mater, the arachnoid and the dura mater. The pia mater lies next the brain, is very delicate, full of small blood vessels, and follows all the convolutions and depressions. The arachnoid lies outside the pia mater, and consists of two layers. They do not follow the pia mater into the sinuosities of the convolutions, but the interior layer penetrates to the underside of the hemispheres, and lines the cavities therein. The dura mater lies outside the arachnoid next the skull. It is pearly white, semi-transparent, thick, and very strong. These membranes envelop not only the brain but also the spinal cord. Outside of the brain, beneath the arachnoid membrane, is the "cerebro-spinal fluid," averaging about two ounces. It serves as a cushion to keep the pressure on the brain cells equal. If the brain rapidly increases in size by growth of new tissue, or turgescence, the amount of fluid decreases, while, in case of atrophy, it has increased to as much as twelve ounces.

The pia mater furnishes to the anterior parts of the brain, appendages of vascular tissue, which furnish a vehicle for the circulation of the blood. A leaf of this tissue from the pia mater, called the *choroidea tela,* lines the lower surface of the body of the fornix, covers the corpora quadrigemina, the posterior commissure and optic thalamus, separating the latter body from the cornu ammonis. Thence a prolongation of it extends into each descending cornu on the anterior side of the hippocampus major. This appendage is called the *choroid plexus.* It is attached by one edge to the tela choroidea, while the other floats loose. Two veins traverse the tela choroidea, into which most of those about the lateral ventricles and from the upper part of the cerebellum, the pineal gland and the corpora quadrigemina, empty. They are called the *venæ galeni.* These pass backward and *often,* first uniting into one, pass on under the splenium of the corpus callosum, into the straight sinus, &c., the blood finally reaching the jugular veins. The silent activities of the brain are large consumers of blood.

The right and left choroid plexuses are joined together at their anterior ends by a cord which passes under the arch of the fornix across the foramen of Munro.

The Ventricles. Some further description of the ventricles, showing their connection and relations to each other, is desirable. First, there is a cylindrical canal of small diameter, which traverses the center of

the spinal cord from its lower extremity to its upper end, where it merges into the medulla oblongata. It also continues through this latter section till it opens into the *Fourth Ventricle.* The hind end of this ventricle is a sharp point, made so by the divergence from each other of the posterior pyramids. From its shape it is called the calamus scriptorius (or writing pen). Across the floor of this space are transverse striæ, or lines, which are called the barbs of the calamus scriptorius. The calamus scriptorius is covered over by a medullary membrane of triangular shape, called the valve of Tarin (*Valvula Tarini*). It is fixed by

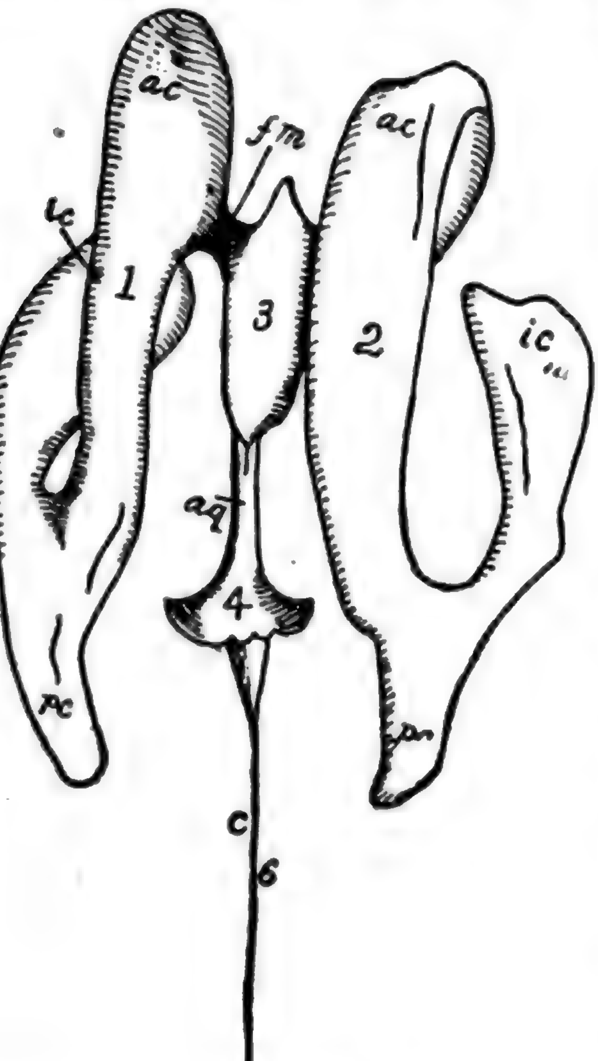


FIG. 276.

FIG.—276.—*Cast Showing Form and relative position of Ventricles of the Brain. (Top view.) (From Gray's Anatomy, by permission.)*
1, 2.—Lateral Ventricles.
3.—Third Ventricle.
4.—Fourth Ventricle.
ac.—Anterior cornu of lateral ventricles.
pc.—Posterior " " "
ic.—Inferior or descending cornu of lateral ventricles.
fm.—Foramen of Munro.
aq.—Aqueduct of Sylvius.
c, 6.—Canal of the Spinal Cord, or sixth ventricle.

its lateral edges to the restiforme bodies, and by its third side, or base, to the posterior vermiform process of the cerebellum. The rest of the roof of the fourth ventricle is formed by the cerebellum, as the greater part of the cavity is filled by its middle lobe, or vermiform process. The lateral walls are formed by the restiform bodies, and the floor by the fibres of the posterior pyramids, which here begin to form the dorsal part of the crura cerebri. The fourth ventricle is bounded at its front end by the valve of vieussens, beneath which is the entrance into the next ventricle, the *aqueduct of sylvius.* This channel passes underneath the corpora quadrigemina and above the crura cerebri, and opens at its front end into the *Third Ventricle.* The third ventricle has for its rear terminus the posterior commissure of the optic thalamus, beneath which is the entrance into the aqueduct of sylvius. Its roof is the middle or gray commissure, and its floor the crura cerebri. Its sides are the inner surfaces of the optic thalami. Near its front end, which is wider than the rear, is a depression in the floor and an opening leading downward into the interior of the *tuber cinereum,* and thence to the infundibulum. In front of this, and at the extreme end, there is a thin lamina of gray matter, called the lamina cinerea. The

edge of this lamina is attached to the *optic chiasm*, which is under the front end of the ventricle and just in advance of the tuber cinereum. Above and in advance of the opening into the tuber cinereum, is the *foramen of munro*, which is the anterior exit of the third ventricle. The foramen of munro is bounded in front by the anterior pillars of the fornix, which arch over it toward the rear, and the openings to the right and left under the edges lead from the foramen to the right and left lateral ventricles. It is Y-shaped, the two prongs connecting above and to the right and left with the lateral ventricles, while the stem descends to connect with the third ventricle. The lateral ventricles, which lie above and to the right and left of the third ventricle, have been described, and mention has been made of the olfactory ventricle which exists in the olfactory bulb in most vertebrates below man, with a canal leading to it from the advanced point of the anterior cornu of the lateral ventricle.

There is one more ventricle to be found in man and monkey, but not in other vertebrates, which is called the fifth ventricle. This is formed in the wall of the septum lucidum by the separation of its two lamina or leaves. It does not connect with the other ventricles, and is supposed by Quain to be derived from the great longitudinal fissure.

Thus this remarkable series of cavities extends from end to end of the cranio-spinal axis, communicating with each other throughout (except the fifth). They are also all lined with the inner membrane of the arachnoid, which, extending through the spinal canal, follows the walls of all the cavities, and finally passes out of the interior of the brain through an opening under the posterior end of the corpus callosum, together with the pia mater, and spreads itself over the external surface of the brain, and the cranial nerves as they leave the cranial cavity.

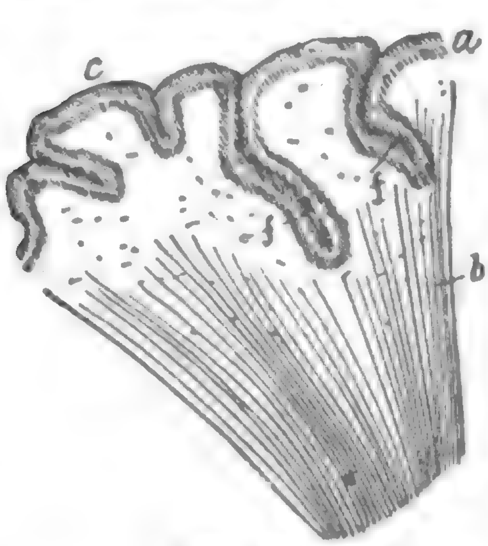


FIG. 277.

FIG. 277.—*Section of convolutions of Posterior lobe of Cerebrum*, showing gray cortex and white band of fibrous nerve matter peculiar to this lobe. (*Owen.*)

Structure of the Cerebrum. The cerebrum and cerebellum are alike in the fact that the gray substance is on the outside arranged in a coat over the surface, while the interior portions of their substance consist of white fibrous matter. This white matter consists of nerve tubules in juxtaposition, and almost infinite in number. They have been described. They are in two series, one of which may be called the converging fibres, since, like the spokes of a wheel, they converge from the periphery, or cortex, toward the optic thalami and internal capsules. The other fibres are the commissural.

They are those which compose the corpus callosum, and anastomosing and connecting at their extremities with the converging fibres, they cross under the falx cerebri from one hemisphere to the other, and tie the two together. The layer of gray matter on the outside is called the cortex. This is from $\frac{1}{12}$ to $\frac{1}{8}$ of an inch in thickness. By the great number of its convolutions its surface is greatly increased. The average surface of an adult cerebrum, counting what is gained by these foldings, is said to be about 670 square inches. There is a certain general plan in these

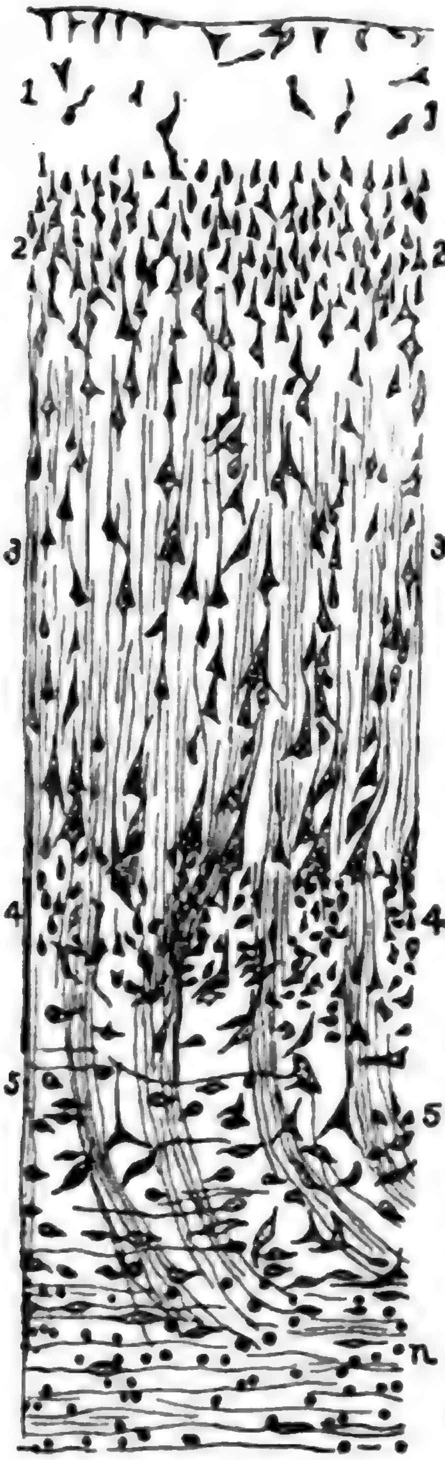


FIG. 278.

FIG. 278.—*Section of Cortex of Cerebrum.*
1.—Superficial layer with scattered corpuscles.
2.—Layer of small pyramidal corpuscles.
3.—Broader layer of pyramidal corpuscles rendered partly into columns separated by nerve fibres.
4.—Narrow layer of small, irregular corpuscles.
5.—Layer of fusiform (spindle-shaped) and irregular corpuscles in medullary center.
(*Quain, after Meynert.*)

convolutions due to race inheritance, and there are certain of the principal ones that are practically alike in human brains, and some are common to man and other mammals, but in the small details they are not alike in any two. Nor are the two hemispheres in any one brain precise counterparts of each other, either in respect to these convolutions or in respect to weight. The gray matter is more abundant in the anterior lobes than in the posterior, and its quantity varies at different ages and in different races. It is greater in races of large stature. It is darker in the negro than in the white man. The composition of the gray matter consists chiefly of cells, with their nerve fibres and connective tissue, and the capillaries for the circulation of the blood, which, originating in the pia mater, penetrate downward into the spaces between the cells of the cortex. From these capillaries, and around them and attached to them, is the connective tissue, which, spreading around, fills all the areolar space, enclosing and holding all the cells with their innumerable ciliary fibres and branching nerve fibres. This is called the *neuroglia*, and all through it the blood capillaries permeate, distributing the vital fluid to the cells and fibres. Around each of the capillaries is a sheath of areolar tissue, through which the nourishment is strained to the nerve fibres and cells. There is a considerable difference in the size of the cells. Those in the bottom layers are

from two to ten times as large as those in the top layers, and those between are correspondingly of intermediate size. In the upper layers there are from 100 to 120 cells to one square millimeter of surface, and $\frac{1}{10}$ of a millimeter in depth. In round numbers this amounts to about 70,000 cells per square inch in the outer layer of gray matter. This, multiplied by 670, the average number of square inches of the outer surface of the cerebrum, gives an aggregate of 46,900,000 cells for this layer, for a depth of $\frac{1}{10}$ of a millimetre, or $\frac{1}{250}$ part of an inch, which is about $\frac{1}{30}$ of the whole thickness of the cortex. It is probably far within bounds to estimate for all the layers of the cortex an aggregate of 500,000 per square inch, and it is not unlikely there are nearer a million, so that we may safely assume that we are possessed of from 300,000,000 to 500,000,000 of these organs in the cerebrum alone. (For description of the cells see chapter 52.) The shape of the cells is probably influenced by the manner in which they are crowded together. Each cell has from one to five fibrous connections. In the adult the cortical substance is seen to be stratified, and observers make out five or six layers. (See fig. 278.) In addition to the insulation of the individual cells and fibres, which has been mentioned, there are groups of related cells which, as groups, are thought to possess more or less insulation from each other. Luys is of opinion that there is a degree of insulation as between the several layers. The layers are differently colored, some being white or gray, others yellowish-red.

The white substance of the brain, under the cortex, consists, as already stated, of the white nerve fibres closely packed together in parallel bundles and masses, yet all insulated from each other by the medullary sheath, as described in chapter 52. By means of these insulated conductors, a stimulus reaching one mass of gray cells, if strong enough, is conveyed to another. The fibres which converge to the crura cerebri, internal capsule, and optic thalamus, keep company with the commissural fibres belonging to the corpus callosum, from the layers of the cortex toward the middle of brain, and when they reach the outside edges of the lateral ventricles, they are seen to separate, the former passing under the ventricles to their respective ganglia, while the latter pass across to the opposite hemisphere over the top of the ventricles.

It has already been observed that the sensory and motor functions of the posterior and anterior columns of the spinal cord are continued into the same relative parts of the medulla oblongata and the cerebral peduncles. The appendages of the brain directly connected with these parts partake of their general functions. Accordingly, the corpora quadrigemina and optic thalami, being on the sensory tracts, with perhaps some exceptional connections elsewhere, are regarded as being in the main sensory ganglia, while the corpora striata being placed on the motor parts of the peduncles, possess motor functions, that is, the move-

ment of the stimulus is downward toward the periphery of the body here, while in the parts pertaining to the sensory tracts it is toward the center, the cortex of the brain. It is evident, therefore, that there is a turning point somewhere, a point at which a stimulus ceases to be a sensory stimulus and becomes a motor stimulus. As already remarked, such points exist in all parts of the spinal cord for the generation of the so-called reflex actions. These points are made up of cells, some of which are placed in the posterior columns of the cord and others in the anterior columns, the former being smaller than the latter. The course of the reflex stimulus is inward from the periphery of the body through the ganglion on the posterior nerve root to the small cells of the posterior columns, thence across to the large cells in the anterior columns, from which it is reflected down and out again to the periphery. The first half of this course is called the afferent and the sensory, the last half is the efferent and the motor.

The first deflection of the stimulus is evidently at the posterior cell, the final one at the larger anterior cell. While the result of these two deflections amounts to a complete reversal of the direction of the stimulus, there is nothing to show any alteration in its nature, the stimulus in reality moving forward throughout its course; the terms afferent and efferent expressing merely the relative effects on the cells or ganglia through which it passes. To each and every cell or ganglion through which the stimulus moves, it is in reality both afferent and efferent, as relates to that cell or ganglion.

The course of those stimuli which are not called reflex, but whose resulting actions are denominated voluntary, instead of merely crossing the spinal cord from the posterior cells to the anterior, pass on up the posterior columns of the cord and along the sensory or posterior tracts of the medulla oblongata and crura cerebri to the optic thalamus, and thence to the small cells in the outer strata of the cortex of the cerebrum. Although on this course, ganglia and cells, at various points, may have been aroused and stimulated, the stimulus has been continued through and past them as an ingoing and afferent stimulus till the small cortical cells are reached. Any further progress of the stimulus makes it outgoing, or motor, for having reached the ultimate ganglia there is nothing left for it but return. Its first return delivery is to the large cells in the lower strata of the cortex, these cells apparently bearing the same relation to the smaller ones that the large cells in the anterior columns of the spinal cord do to the small ones in the posterior columns. From these large cortical cells the stimulus is continued downward into the anterior parts of the internal capsule, thence on down the anterior fibres of the crura cerebri, the medulla oblongata and the spinal cord, to the motor nerves leading to the muscle or gland to be moved.

CHAPTER LVIII.

COMPARATIVE ANATOMY OF THE BRAIN.

The nervous system of the amphioxus is the most simple possessed by any vertebrate. (See fig. 63.) The only sense organs this little animal hasare a depression surrounded by cilia, near the front end of the animal, supposed to be an olfactory organ, and a pigment spot a little further back, supposed to be an ocellus, or the rudimentary beginning of an eye. Nerve connections to these from the spinal cord are rather inferred than proved. The medulla spinalis, or spinal cord, extends from the head to the tail, as in other fishes, and gives off dorsal and ventral branches at regular intervals, corresponding in number to the muscular segments. Two pairs, however, appear to have already received some degree of specialization. These are the first and second pairs. The first pair, which are small ones, run to the parts above the mouth, and may represent the seventh and eighth pair of the higher vertebrates, of course not yet specialized to the uses to which they are afterward put. The next pair are supposed to represent the trigeminum, or fifth pair, and the par vagum or pneumogastric (tenth pair). This nerve, after leaving the spinal cord, sends out a branch upward and backward, parallel with the spinal cord and connecting with the segmental nerves of the back; while the main stem bends down and passes backward, connecting with the ventral segmental nerves. No part of the spinal cord of the amphioxus contains any ganglionic masses or enlargements, and these great nerves must be considered as constituting its principle condensing organ.

Among the lower vertebrate brains are those of the Hags and Lampreys. In these fishes, in common with the Amphioxus, the spinal cord is "flattened, opaline, ductile and elastic." In other fishes "it is inelastic, opaque and cylindrical, or subdepressed." (*Owen.*) The cerebellum of the Lamprey is a mere commissure, or band of fibres, stretching across the upper end of the fourth ventricle. It is but little better in the Sturgeon. (See fig. 281.) But the development of the cerebellum does not appear to keep pace with the general organization of the animal, for in the otherwise advanced Lepidosiren, the cerebellum is as elementary as that of the Lamprey. (Fig. 290.) Owen shows the development of that part of the brain among the fishes to be in accordance with the activity of the animal. The Sharks and Saw-fish, therefore, which are among the most active fishes, have a greatly advanced cere-

bellum. The Tunny has the largest and most highly organized cerebellum of all. This fish is very active, and is also nearly equal to the warm-blooded animals in some of its physical make-up. In the shark,

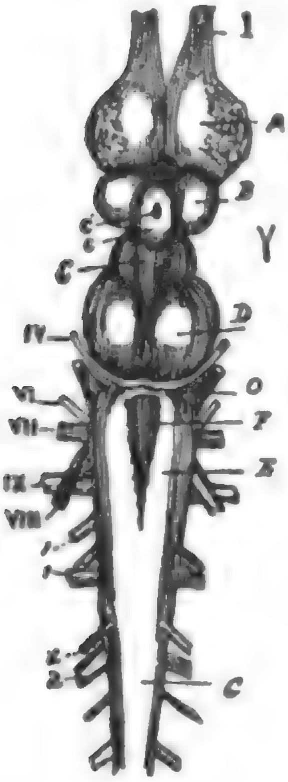


Fig. 279.

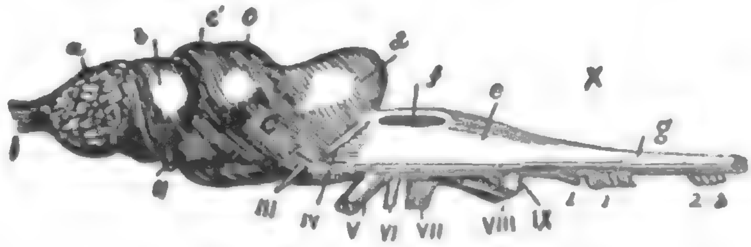


Fig. 280.

Fig. 279.—*Top view of the Brain of River Lamprey (Petromyzon fluviatilis.)*

Fig. 280.—*Side view of same.*

I.—Olfactory nerves.	*A, a.*—Olfactory lobes.
II.—Optic nerves.	*B, b.*—Cerebral hemispheres.
III.—Motor oculi nerves.	*C, c.*—Thalamencephalon.
IV.—Pathetic nerves.	*D, d.*—Optic lobes.
V.—Trigeminal nerves.	*E, e.*—Medulla oblongata.
VI.—Abducens nerve.	*F, f.*—Fourth ventricle.
VII.—Facial & auditory nerves.	*O.*—A narrow band between *F, f* and *D, d* is the *Cerebellum.*
VIII.—Glosso pharyngeal and Vagus nerves.	*G, g.*—Spinal cord.
IX.—Hypoglossal nerves.	c.—Pineal gland.

1, 1. 2, 2.—Sensory and motor roots of the first two spinal nerves. (*Huxley.*)

this organ covers not only the fourth ventricle but a good share of the optic lobes also. (See fig. 286.) In the saw-fish it covers the optic lobes and laps over upon the cerebrum. But in these active fishes it is not merely largest, it is also the best developed; for

Fig. 281.—*Brain of Sturgeon.*
R.—Olfactory lobes.
P.—Cerebral hemispheres.
O.—Optic lobes.
C.—Cerebellum.
A.—Fourth ventricle.
TV.—Vagal columns—origin of the Vagus [Nerves.

Fig. 282.—*Brain of Chimera Monstrosa,* a cartilaginous fish with complete cranial wall.
R.—Olfactory lobes.
1.—Olfactory nerves.
P.—Cerebrum.
O.—Optic lobes.
B.—Cerebral Crura.
C.—Cerebellum.
TV.—Trigeminal lobes.
2.—Optic nerves—they do not decussate. (*Busch.*)

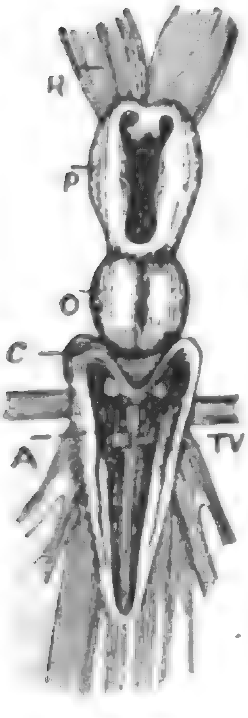


Fig. 281.

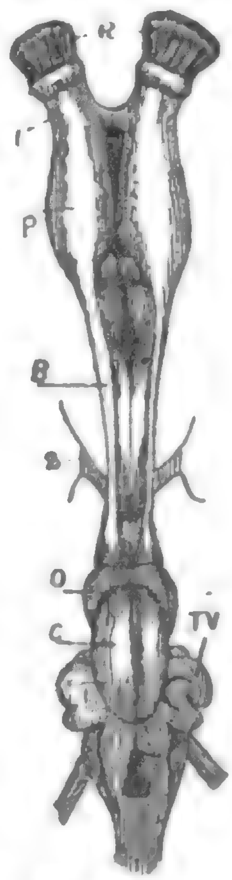


Fig. 282.

its surface is increased by transverse folds, as seen in fig. 286. It is variously placed in different fishes, and its shape greatly varies. In the cod it is flat and tongue-shaped, and covers the fourth ventricle. In the amblyopsis it is a hemispherical bulb, extending well over the optic lobes—which is an unusual arrangement, owing to the small use this animal makes of eyes. There is generally some gray

matter mixed with the white fibres of the cerebellum; and there is usually a cavity, or ventricle, in the cerebellum of the osseous fishes which connects with the fourth ventricle. The Eel, Tench and Lepidosteus (Gar pike) are, however, destitute of this ventricle, their cerebellum being solid. There is no arbor vitæ in the cerebellum of any fish except the Tunny and Shark.

The part of the brain which includes the cerebellum and the medulla oblongata, with their appendages, is denominated, by Owen and others, the *Epencephalon*. The greater part of the nerves controlling the active movements of the body, have their roots in this part of the brain. The great trigeminum and the vagus, or pneumogastric, which are particularly of great importance to the motor activities, originate near each other in the restiform tracts of the medulla oblongata. In the fishes, especially the active ones, these nerves are very large, and in some cases their roots are swollen into large masses called lobes. Trigeminal lobes are shown in the Chimera Monstrosa, fig. 282. In the Skate these lobes are very large and convoluted. In the Torpedo these lobes are blended with the vagal lobes, and are of vast size. They are, in this case, called electric lobes. These lobes are not much developed in most of the osseous fishes. There is a band of fibres stretching across beneath the cerebellum, called the restiform commissure. This is very large in the Carcharias (Shark), amounting almost to an additional lobe of the cerebellum. There cannot be any doubt that the epencephalon is the condensing and directing apparatus for the physical movements of

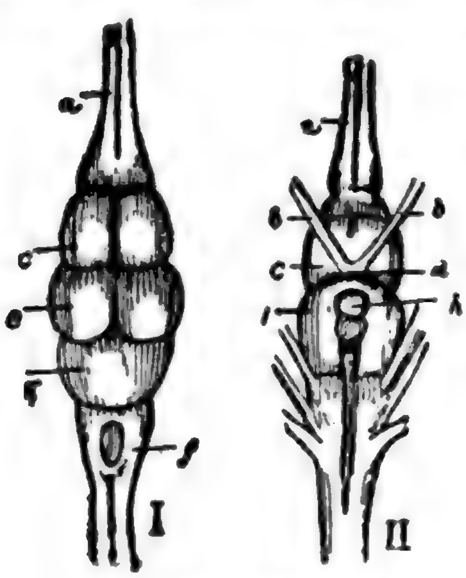


FIG. 283.

FIG. 283.—*Brain of Lepidosteus Semiradiatus.*
I.—Top view.
II.—Underside.
a.—Olfactory Nerves.
b.—Optic Nerves.
c.—Cerebral Hemisphere.
d.—Optic Chiasm.
e.—Optic Lobes.
f.—Medulla Oblongata.
g.—Cerebellum.
h.—Pituitary Gland.
i.—Hypoaria, or Inferior Lobes.

the animal. The minor appendages depend for the state of their development upon the peculiar habits of activity affected by the animal.

The next division of the vertebrate brain is often called the *mesencephalon*. This division in the fishes includes the optic lobes, which are built on top, or on the dorsal side, of the spinal medullary stem, and in most fishes two other bulbs, which are developed on the opposite or under side, and which are called *Hypoaria*, or lobi inferiores. The hypoaria are well developed in the cod, fig. 289. They are formed upon the anterior or under side of the anterior pyramids. In the cod, and some others, they each have a hollow inside, or ventricle, called the hypoarian ventricle. Underneath the hypoaria is a median and single body, vascular and medullary, called the

hæmatosac. It appears to resemble the hypophysis, or pituitary gland, which depends from the third ventricle in front of the optic lobes.

These hypoaria and the hæmatosac are not found in either the lowest or highest orders of fishes. In the Myxine, among the lowest, the an-

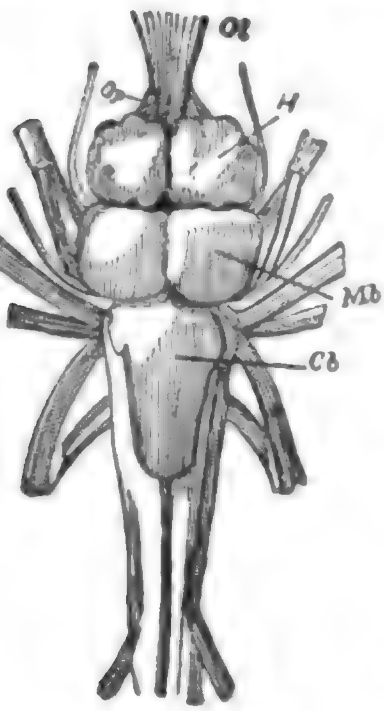


FIG. 284.

FIG. 284.—*Brain of Pike-fish. Top view.*
Ol.—Olfactory lobes lying above the Optic nerves, *Op.*
H.—Cerebral hemispheres.
Mb.—Optic lobes.
Cb.—Cerebellum.

terior pyramids swell out into a small protuberance beneath the optic lobes, and this is perhaps an elementary form of the hypoaria. But the same thing is seen in the, in many respects, advanced Lepidosiren. (Fig. 290.) It may be elementary in this animal also, since from its inactive habits its entire hind brain is in a backward condition, but more likely in both this and the Polypterus, which is another salamandroid fish, these organs are rudimentary from retrogression. In the Shark these columns swell out laterally and form protuberances on the sides of the crura cerebri, separated from each other by the vascular matter forming the infundibulum on the floor of the third ventricle, in advance of the base of the optic lobes. These formations are to be regarded as modifications of the hypoaria, which occur in most of the osseous fishes. Just behind the hypoaria, in the osseous fishes, there is a band of transverse fibres con-

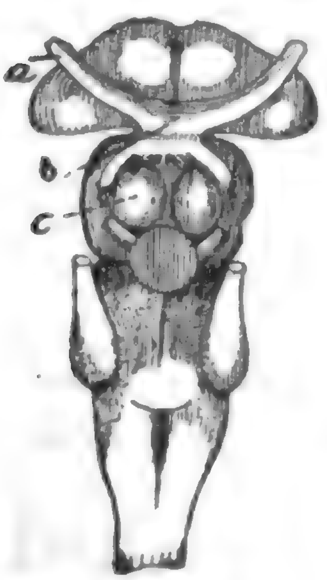


FIG. 285.
P.—Cerebral hemispheres.
O.—Optic Lobes.
C.—Cerebellum.
N.—Lateral bulbs from the anterior pyramids answering to the Hypoaria of the Cod, &c.

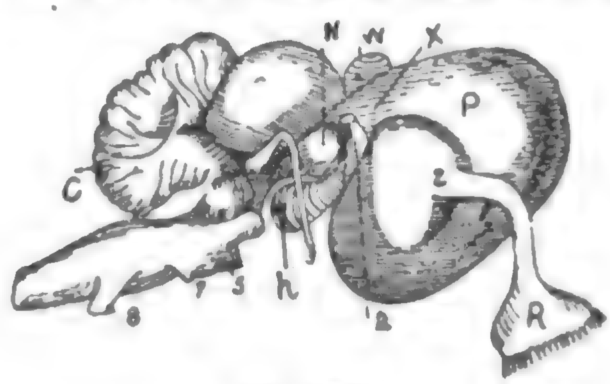


FIG. 286.

FIG. 285.—*Brain of Skate.* (*Raia.*) (*Underside.*)
a.—Optic Nerves.
b.—Cross fibres connecting the same.
c.—Hypoaria.

FIG. 286.—*Brain of Shark—Carcharias.*
R.—Olfactory Lobes, with olfactory nerves at their extremities.
z.—Olfactory Crura.
X.—Cerebral Crura.
W.—Pineal Gland.
h.—Pituitary Gland.
2.—Optic nerves.
5, 7, 8.—Fifth, seventh and eighth pairs of nerves.

necting together the two anterior pyramids. It is called the ansulate commissure, and is to be regarded as the early intimation of the pons

varolii. The optic lobes are formed upon the posterior parts of the medullary stem, and their function is chiefly, though perhaps not exclusively, the condensation of the stimuli of sight. A part of the roots of the optic nerve are found in the optic lobes, and part are to be traced in the hypoaria. The optic lobes vary greatly in size. In the nearly blind cave fish, Amblyopsis speleus, both these lobes and the optic nerves are very small, and less in size than either the cerebellum or cerebrum. They are likewise smaller than these organs, relatively, in the chimera and the shark. They exist in the myxine, a blind parasite, from which circumstance Owen infers that their function relates to something more than merely sight stimuli. But in this fish perhaps they are rudimentary. In most fishes they are larger than the cerebral lobes, in a few, as the polypterus and lepidosiren, they are larger than the cerebellum but smaller than the cerebrum. In the Sturgeon, Polypterus, Lepidosiren, Amblyopsis and Loach (Cobitis), the optic lobes are scarcely separated from each other, but run together. They are distinct in most osseous fishes, but are connected together by a commissure, generally the anterior commissure passing across from one to the other in front of the entrance to the third ventricle. These lobes are generally hollow, or contain ventricles, one in each. On the floor of each of these there are usually one or two bulbs, or tubercles, called optic tubercles. In the Cod, Salmon, Pike and Perch there are four of these, two in each lobe; in the Carp and Herring there is one in each lobe. The Sharks and Rays, the Sturgeon, Polypterus and Lepidosiren do not possess these tubercles. Those which do have the tubercles also possess another process inside the ventricle, called the "torus semicircularis." This is a sort of an elongated tubercle, which is attached to the floor of the ventricle in advance of the "optic tubercles," and arches backward over them to a greater or less extent. They are large in the Carp. Neither these ventricular tubercles nor the torus are found in any animals besides fishes. According to Owen, these *tori* are not to be regarded as homologous with either the optic thalamus or corpus striatum. The external shell of the optic lobes is composed of white and gray matter. These are shown blended upon the surface.

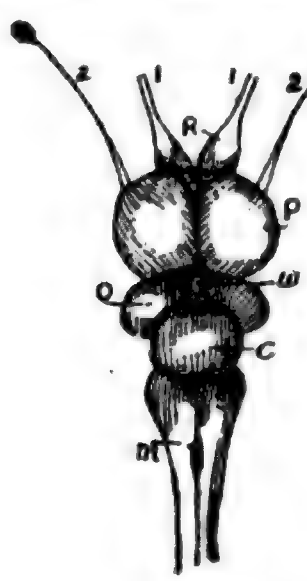


FIG. 287.

FIG. 287.—*Brain of Amblyopsis, ("obscure-eyed") cave fish.*
c.—Cerebellum extending over the optic lobes.
o.—Optic lobes. P.—Cerebrum.
w.—Pineal gland. R.—Olfactory lobes.
m.—Medulla oblongata. 1.—Olfactory nerves.
2.—Optic nerves greatly reduced by disuse.
(No pons varolii in fishes, and no lateral lobes to the cerebellum.

The restiform columns of the medulla oblongata pass into the base

and exterior wall of the optic lobes, and into the walls of the third ventricle. A small part only, in osseous fishes, are continued past the third ventricle into the cerebrum. This shows, as will be seen, that a comparatively small portion of the activities of the fish are governed by reflection and memory.

The next division of the brain is represented in the embryo by what Carpenter calls the vesicle of the third ventricle. Huxley denominates it the Thalamencephalon. Owen includes it with the optic lobes in the Mesencephalon. The constant parts of this division are the pineal gland, or conarium, above the third ventricle, and the pituitary gland, or hypophysis, below it. These glands are to be found in all osseous fishes, as well as in birds, reptiles and mammals, including man. The

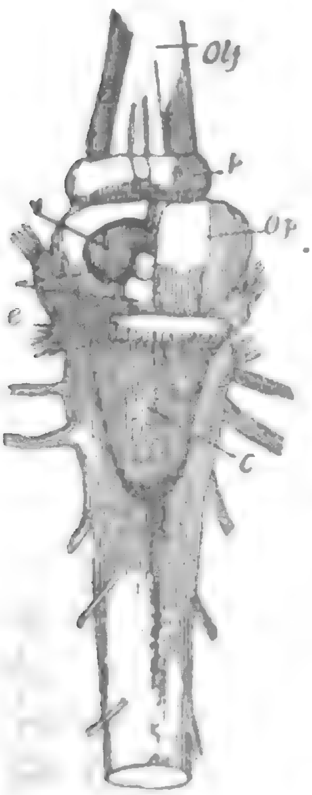


FIG. 288.

FIG. 288.—*Brain of Cod. Top View.*
Olf.—Olfactory Lobes.
P.—Cerebrum.
C.—Cerebellum.
Op.—Optic Lobes. Top of the left one removed, showing
V.—The ventricle and
e.—Two of the four interior optic tubercles.

FIG. 289.—*Brain of Cod. Underside.*
P.—Cerebrum.
Py.—Pituitary Gland.
O.—Optic Lobes.
n.—Hypoaria.
h.—Hæmatosac lying between the hypoaria.
2.—Optic Nerves.
3, 5, 6, 7, 8.—Cranial nerves of corresponding numbers.
(*Owen.*)

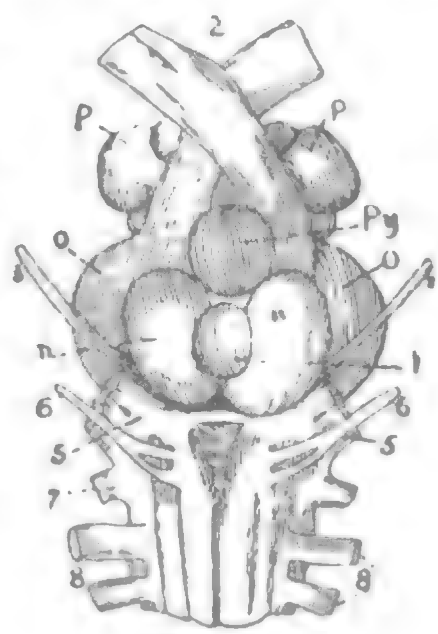


FIG. 289.

optic thalamus itself is either not developed at all or is extremely elementary in the fishes. The pineal gland is usually a pyramidal sac joined at its base to the walls of the third ventricle between the optic and the cerebral lobes. The apex is attached to the roof of the cranium. It is commonly composed of a membranous substance well supplied with blood vessels. It has this character in the sturgeon, lepidosiren and shark. In the carp and herring tribes there is medullary matter incorporated in the membrane, and in some fishes there is gray matter.

The pituitary gland is likewise a very vascular body, at the apex of an inverted conical, membranous sac, the infundibulum. It is attached, base upward, to the underside of the crura cerebri, its cavity opening into the third ventricle.

The fibres of nerve matter from the spinal cord, after forming the crura cerebri, are continued forward to the bodies called the cerebral hemispheres, in fishes; bodies which, in the higher vertebrates, appear to constitute only the corpora striata. This division of the brain is

called the Prosencephalon, and it consists simply of the two bulbs called the hemispheres. A few of the medullary fibres, which continue into it from the spinal cord, pass on along its base into the most forward division of the brain, called the Rhinencephalon, which is composed solely of the olfactory lobes and the medullary stem, which may connect them with the cerebral lobes. The cerebral lobes vary greatly in size in different fishes. Thus in the Cod, Carp, Globe fish, Bream, Perch, Stickleback, Gurnard, and Lepidosteus, they are smaller than the optic lobes.

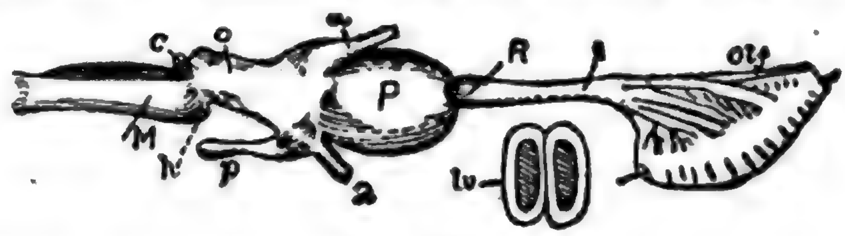


FIG. 290.

FIG. 290.—*Brain of Lepidosiren (Mud fish.)*
C.—Cerebellum.
o.—Optic Lobes.
w.—Pineal Gland.
P.—Cerebral Hemispheres.
R.—Olfactory Lobes.
1, Olf.—Olfactory Nerves.
M.—Medulla Oblongata.
h.—Protuberance of anterior pyramids.
p.—Pituitary Gland.
2.—Optic Nerves.
lv.—Cross-section of Cerebrum, showing the lateral ventricles. (*Owen.*)

In the Shark (fig. 286) they are as large as the cerebellum and optic lobes together. In the Gar fish, Herring and Lump fish the cerebrum is smaller, relatively, than in the Cod. In the Myxine it is smallest of all. In the Polypterus and Lepidosiren it is larger than all the rest of the brain.

The cerebral lobes of fishes are composed chiefly of gray vascular nerve matter, through which the white fibres radiate. The surface is pinkish in color, and nodulated. In the Cod and Amblyopsis there are two or three convolutions, but as a rule the cerebral hemispheres are smooth, from the Myxine, in which they are smallest, to the Sharks, in which they are among the largest, and the Lepidosiren and Polypterus, which are among the most highly organized fishes. In general, these lobes are solid, but there are ventricles in those of the Lepidosiren, and these communicate with ventricles in the olfactory lobes. In the Shark there is an elementary ventricle in the shape of a fissure in the under anterior part of the lobe, into which a fold of a vascular membrane, answering to the choroid plexus, is inserted. This fissure also extends into the olfactory lobe. As a rule, the cerebral lobes of fishes are distinct from each other, and are connected by a commissure which is homologous with the "anterior commissure," which, in more highly developed animals, connects the two hemispheres. In a few families of fishes these lobes are not separated at all.

Observing that the ventricles of the cerebral lobes of Lepidosiren and Sharks are excavated in the body of the lobes themselves, it is doubtful if these ventricles are the homologues of the lateral ventricles which occur in higher brains. The ventricles in the cerebellum, the optic lobes

and olfactory lobes of fishes, become filled in and consolidated in mammals, and it appears that the same thing happens to the cerebral lobes, the cerebrum of the fish becoming the corpora striata of the mammal, and forming a floor, over which the cerebral lobes are erected as a superstructure, the lateral ventricles being entirely above the substance of the floor and not in it; nevertheless the cerebral lobes of the fish are all to it that the cerebrum is to the mammal, because the composition of their cortex of mingled nerve fibre and vascular neurine is the same as that which forms the mammal convolutions.

In the Pleuronectidæ (flat-fish) neither the cerebral lobes, optic lobes or hypoaria are symmetrical. (See fig. 81.) The olfactory lobes are always distinct in fishes, and never united with each other by commissures. They are often close together at their points of connection with the cerebral lobes. Sometimes they do not join the cerebral lobes directly, but are connected each by a stem of medullary matter called a *Crus.* These crura are sometimes so short as to show only an indentation, as in Lepidosiren (fig. 290); in other cases the crura are long, supporting the olfactory bulbs on their ends, as in Sharks (fig. 286, *z*). The olfactory nerves start from the bulbs in front and form connection with the organ of smell. There is no gray matter connected with the olfactory nerve (or other nerves of conduction), but there is gray matter contained in the crura mingled with the white fibres. As a rule, the olfactory lobes and crura of fishes are solid. Lepidosiren and Shark are exceptions, as noted above.

The optic nerves and eyes of fishes are generally large. In Flat fishes one optic nerve is smaller and shorter than the other. The optic nerves are connected by filaments with the hypoaria, as well as with the optic lobes. In ordinary osseous fishes, fibres from the optic nerves can be traced into the cerebellum also. The optic nerves of fishes decussate, or cross each other, but each nerve crosses over without giving any of its fibres to the other, as in the mammals. (Fig. 81.) At the point of crossing, the nerves are flattened, sometimes one nerve and sometimes the other being on top. In most osseous fishes, the optic nerve consists

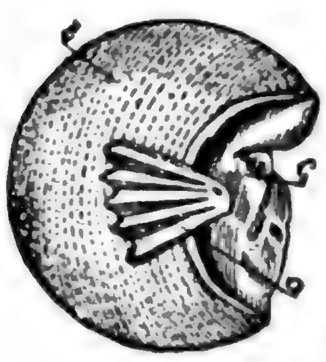


FIG. 291

FIG. 291.—*Plaited Optic Nerve of a Mullet.*
a.—Optic nerve deprived of its sheath, showing its plaited disposition.
b.—Sclerotic Coat of the Eye, through which the nerve passes.
c.—Retina, in which the nerve terminates.

of a plate composed of membrane and nervous matter, which is folded into a number of plaits, a structure which usually prevails throughout the length of the nerve, from its cerebral attachment to the eyeball; in some instances the inner surface of the optic lobe is also folded, and in all, the plaits may be ob-

served to be faintly contained upon the retina, which is formed by the unfolding of the nerve. (See fig. 190.)

Other Nerves. The fifth nerve, Trigeminus, is enormous in all fishes. In the Lancelet the fifth nerve distributes many filaments to the expanded sensitive integument, which represents the head and forms the sides of the wide mouth, and also supplies the oral tentacles. In the myxinoids the same nerve supplies both the muscles and the integuments of the head, the tentacles, the nasal tube, the mucous membrane of the mouth and tongue, the hyoid and palatal teeth, and the pharynx. The trigeminus supplies the same parts in the Lamprey, but by fewer primary branches. "That which sends filaments to the rectus externus and rectus inferior of the eyeball, is continued forward beneath the skin, and resolves itself into a rich plexus, which supplies the thick cirrate border of the suctorial lip; the nerves to the muscular parts of the jaws and tongue arise distinct from the fifth nerve, and their trunk may be regarded as a facial nerve. The auditory appears to be a primary branch of the fifth, in Skate. Swann calls it glosso pharyngeal. In the Cod, and all fishes above Dermopteri, the auditory is a distinct nerve rising between the fifth pair and the vagus."

There is no spinal accessory (eleventh pair) in fishes or snakes, but it is to be found in mammals, birds, and all reptiles, except snakes. The general position of the points of exit from the brain of the nerves, is practically the same in all the vertebrates in which they exist. The spinal nerves generally correspond in number with the ribs. They are in pairs, and pass out on each side through the vertebræ, or between them.

Reptiles. In a newt weighing 39 grains, the brain weighs $\frac{1}{7}$ of a grain, and in the large Sirens, Amphiumes and Menopomes the brain is relatively still smaller. In these reptiles there is a fourth ventricle, as in fishes. It is bounded at its upper end by a feeble rudiment of a cerebellum, formed by the confluence and convergence of the sides of the ventricle. The Axolotl has a long elliptical optic lobe, which gives off small optic nerves below. It has the pituitary and pineal glands, the latter large and extending from before the optic lobe upon the rear of the interspace between the cerebral hemispheres. These cerebral hemispheres are twice as long and broad as the optic lobe, are smooth and hollow like Lepidosiren. Olfactory lobes are seated upon the fore and outer part of the hemispheres. Cerebral ventricles continue into the olfactory lobes. In serpents the cerebellum is smaller than the optic lobes, and the optic lobes are less than one-fourth as large as the cerebrum. The cerebellum covers the greater part of the fourth ventricle, and is a semicircular lobe somewhat depressed or flattened. The optic lobes are hollow, and are crossed by a transverse fissure near the

hind end, as well as divided by a longitudinal median fissure. So there are four bulbs answering to the *quadrigemina*, the front ones, answering to the nates, being much the largest.

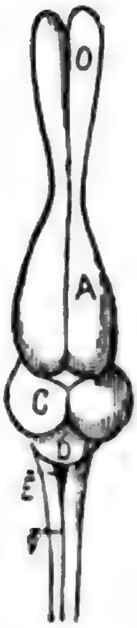


FIG. 292.

FIG. 292.—*Brain of Lizzard, top view.* (*John Anderson.*)
O.—Olfactory lobes. *D.*—Cerebellum.
A.—Cerebral hemispheres. *E.*—Fourth ventricle.
C.—Optic lobes. *F.*—Spinal cord.

The cerebral crura, in advance of the optic lobes, show slight enlargements like optic thalami; after passing which the fibres of the crura pass into the hemispheres. The hemispheres are hollow, and are separated by the thin wall belonging to each. Into each of their ventricles a corpus striatum projects from the under and outer side. The septum between the two hemispheres is perforated for the passage of a "choroid plexus." The ventricles are continued forward into the olfactory lobes, which are very large. In lizzards the optic lobes are relatively larger than in the snakes, the eyes being correspondingly more active. They constitute one pair, however, instead of two, and are hollow. In Turtle (Chelone) the cerebellum is an arched body of equal thickness throughout, covering the upper end of the ventricle. (Fig. 293.) The rest of the ventricle is covered by a web of vascular matter derived

FIG. 293.

FIG. 293.—*Side view of Brain of Turtle* (*Chelone.*)
FIG. 294.—*Top view of same.*
P.—Cerebrum.
C.—Cerebellum (in 294 it is raised to show the fourth ventricle.)
F.—Fourth ventricle.
O.—Optic lobes.
V.—Ventricle in same.
R.—Olfactory lobes.
S.— " nerves.
k.—Ventricle in olfactory lobes.
X.—Ventricle in cerebrum, containing corpus striatum and communicating with ventricle in olfactory lobe.
W.—Space between *O* and *P*, covered by pineal gland.
m, m.—Bristle, showing communication between optic ventricle and fourth ventricle.
a.—Optic nerves.
d.—Swelling of same in passing over the crura cerebri.
(*John Anderson.*)

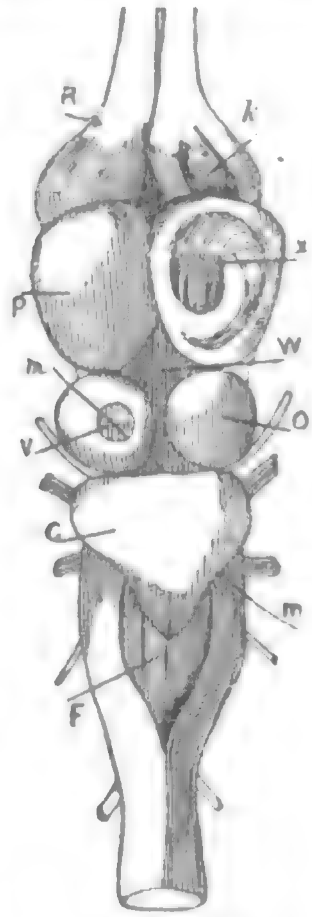
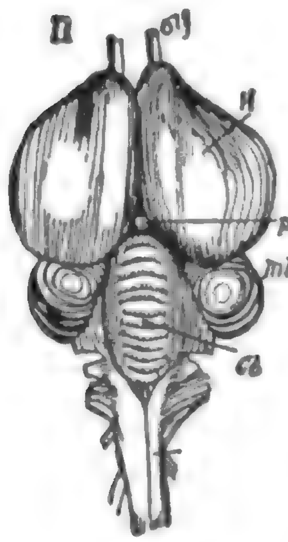


FIG. 294.

from the sides of the medulla oblongata. The optic lobes are smooth and hollow, their ventricles communicating with the third and fourth ventricles. The aqueduct of sylvius lies below and between them. There is a pituitary gland below the third ventricle and the pineal gland above. The crura cerebri

bend down between the cerebellum and the cerebrum, sinking the optic lobes to a plane below the other ganglia. (Fig. 293.) The hemispheres are smooth, but have ventricles, and in them are formed the corpora striata and choroid plexus. Anterior to the optic lobes are the thalami optici, formed upon the crura cerebri. The brain of crocodile differs only in minor matters from that of the turtle. The cerebral lobes are relatively larger. The cerebellum is gashed by a transverse fissure, or fold. The optic lobes have each a ventricle, into which a convex body projects, something after the manner of the corpus striatum into the cerebral ventricle. The olfactory lobes at first near the cerebrum, move off with the growth of the animal, and remain connected by crura.



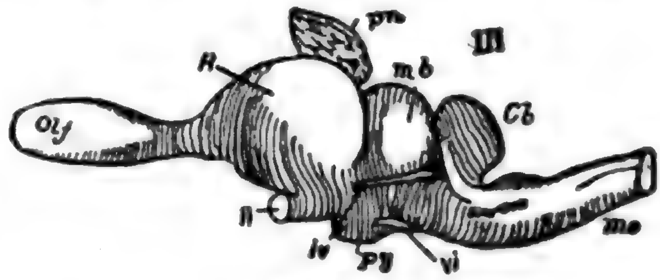


FIG. 295.

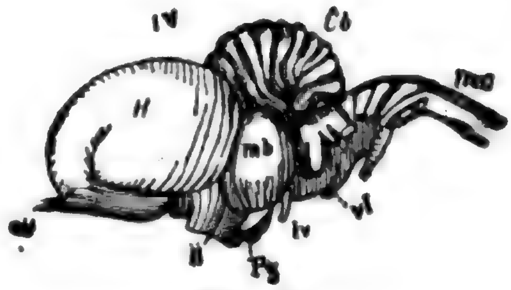


FIG. 298. FIG. 296. FIG. 297.

FIG. 295.—*Side view of Brain of Lizzard (Psammosaurus Bengalensis).*
FIG. 296.—*Top view of same.*
FIG. 297.—*Side view of Brain of Turkey.*
FIG. 298.—*Top view of same.*

Olf.—Olfactory lobes (in all).
H.—Cerebral hemispheres.
pn.—Pineal gland.
mb.—Optic lobes.
py.—Pituitary gland.
Cb.—Cerebellum.
mo.—Medulla oblongata.
ii.—Optic nerve (second nerve).
iv.—Pathetic nerve (fourth nerve).
vi.—Abducens (sixth nerve). (*Huxley.*)

There is, in reptiles, an anterior commissure, usually small. There is no pons varolii.

The spinal cord of birds, like that of other vertebrates, expands in volume opposite the parts related to the limbs—wings and legs. The part of it developed in the tail extremity of the embryo, shrinks up into a mere filamentary trace of its first condition, and does not fill up the neural canal. It becomes larger in the sacral region as the legs grow. The spinal cord becomes more slender in the dorsal region, and expands again near the base of the neck at the shoulders, where the nerves of the fore limbs join it. There is a ventral and a dorsal side to the spinal cord, and a canal through the middle. The ventral side is nearly split in two by a longitudinal fissure, which cleaves it almost to the canal. There is also a dorsal fissure not so well marked or deep as

the ventral fissure. This fissure widens out in the sacrum, forming a lozenge-shaped gash, or ventricle, which is denominated the sinus rhomboidalis. In the medulla oblongata there is another widening of the fissure forming the fourth ventricle, as in the mammals, including man. The enlargements of the spinal cord, opposite the fore and hind limbs, are in proportion to the activity and power of the limbs, as we should naturally expect. Thus, in flying-birds the enlargement at the part relating to the wings is the larger one, while in the Runners, *cursores*, Scratchers, *rasores*, and others which make much use of their legs, the posterior enlargement is the greatest.

The optic nerves of birds are usually very large. They originate from the whole outer surface of the optic lobes, and from the optic thalami as well; the fibres from these two origins immediately joining to form the nerve. A part of the fibres in each nerve remain on the side on which they originate, and connect with the eye on that side, while the rest "decussate," crossing over to the opposite side. After the decussation the nerve is seen to be composed of longitudinal plates piled one upon another; doubtless they are plaits, or folds, of a flat nerve, as in the fishes. (*Owen.*)

It is worthy of observation that although birds are now toothless, there are some, as the *anatidæ* (ducks), and other water fowl, whose beaks are notched or indented on the edges, and that to each of these dentations several nerve filaments are distributed. These are from the superior and inferior maxillary branches of the fifth pair. There is no gustatory branch to the tongue, that organ being one chiefly of prehension and not of taste, in birds. (*Owen.*) The sympathetic nerve system in birds, partakes, in some particulars, of the character of that of reptiles; in others, of mammals.

Fig. 299.

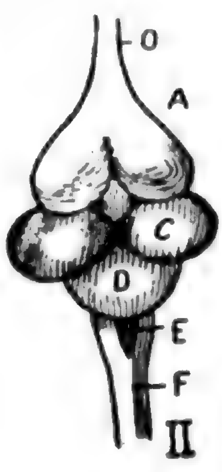


Fig. 300.

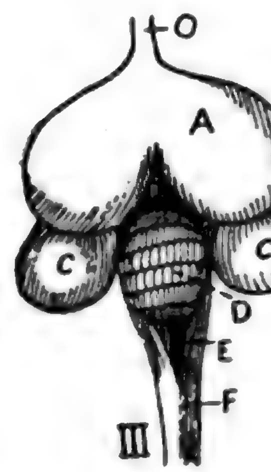


Fig. 301.

Fig. 299.—*Embryo Chick 8 days.*
Fig. 300.— " " *16* "
Fig. 301.— " " *20* "
Letters same in all.
O.—Olfactory lobes.
A.—Hemispheres of Brain.
B.—Optic thalamus (fig. 299. It is covered by the hemispheres in figs. 300 and 301.)
C.—Optic lobes—*Corpora Bigemina.*
D.—Cerebellum.
E.—Fourth ventricle.
F.—Spinal cord.
(*John Anderson.*)

The brain of the embryo chick at eight days, shows the divergence of the posterior pyramids and the formation of the fourth ventricle, the rudimentary cerebellum at its upper end, and the *corpora bigemina*, or optic lobes, and the hemispheres well started, and between them the optic thalami (see fig. 299) lodged upon the crura cerebri. The optic

lobes are in contact with each other, and are oblong, smooth, white vesicles of nerve matter. These characters, and the rudimentary state of the cerebellum, are representatives of the permanent condition of the brain of the adult batrachians. At the end of the sixteenth day, the brain of the chick has acquired the appearance represented in fig. 300, and resembles the brain of the Lizzard. (Fig. 292.) The cerebellum has grown over the fourth ventricle; its surface is smooth, as in the Turtle and Crocodile; the optic lobes have become spheroidal in shape, and the hemispheres cover up the optic thalami. About the time of hatching, the brain has the appearance represented by fig. 301. The cerebellum has largely increased, grown forward between the corpora bigemina, pushing them apart, and its surface covered with gray matter is corrugated by transverse folds. In the mature bird, there is a rudimentary fissure of sylvius, a mere depression where that fissure exists in the mammals. The hemispheres are connected together by the anterior or round commissure. The corpora striata are relatively very large in birds, and form, in fact, the greater part of the cerebrum, but they do not possess the alternate striations of white and gray, shown in the higher mammals. In the latter respect they agree with adult reptiles and the embryo of the mammalia. The lateral ventricles have no descending cornu. They are separated from each other by a thin partition of medullary matter. Beneath the posterior part of this wall there is an orifice by which the two ventricles communicate with each other and also with the third ventricle. Just above the orifice is a small projection of medullary matter, which is an undeveloped beginning of the *fornix.* The optic thalami are small and not connected by the commissure, as in the Lizzard. The pineal gland is attached behind to the valve of Vieussens, and its peduncles connect it with the optic thalami. The corpora bigemina, or optic lobes, have ventricles, which open into the aqueduct of sylvius. The third ventricle opens below into the infundibulum, at the bottom of which is a large pituitary gland. The cerebellum has but one lobe, the median, which answers to the verniform process of the higher mammals, while the lateral lobes are wanting, or nearly so, and there is no pons varolii. The cerebrum and cerebellum of Birds are superior in size to those of the Reptiles, while the cerebellum is superior in structure by reason of its folds. There is great relative difference in the sizes of the brains of birds, but it chiefly relates to the optic lobes. The cerebral hemispheres remain small and unconvoluted in all. (*Cuvier.*)

Mammals. Owen proposes a classification of mammals, based upon their brain development. In this classification the monotremes and marsupials are placed as a sub-class at the bottom of the series, and are named *Lyencephala* (loose-brained). The fig. 304 of the brain of the

Dasyure, a marsupial, shows the olfactory and optic lobes exposed from above as well as the cerebellum. In these brains there is no fully developed corpus callosum. The cerebral hemispheres are united by a *round* commissure, and by a 'lyra' and hippocampal commissure. This appears to be the forerunner of the corpus callosum, which is developed in the higher mammals. In the monotremes the optic lobes are still a single pair, as in birds.

Owen's Classification of Mammals based on Brain Development. Class Mammalia.

Sub. Class		Order	Genus or Family	Example
Archencephala, Ruling Brain		Bimana	Homo	Man
Gyrencephala Convoluted Brain	Unguiculata with claws	Quadrumana	Catarrhina Platyrrhina Strepsirhina	Ape Marmoset Lemur
		Carnivora	Digitigrada Plantigrada Pinnigrada	Dog Bear Seal
	Ungulata with hoofs	Artiodactyla	Omnivora Ruminantia	Hog Sheep
		Perissodactyla	Solidungula Multungula	Horse Tapir
		Proboscidia	Elephas Dinotherium	Elephant Dinothere
	Mutilata Hind limbs Wanting	Sirenia	Manatus Halicore	Sea-cow Dugong
		Cetacea	Delphinidæ Balenidæ	Porpoise Whale
Lissencephala Smooth Brained		Bruta or Edentata	Bradypodidæ Dasypodidæ Edentula	Sloth Armadillo Ant-eater
		Cheiroptera	Frugivora Insectivora	Rousette Bat
		Insectivora	Talpidæ Erinaceidæ Soricidæ	Mole Hedgehog Shrew
		Rodentia	Non-Claviculata Claviculata	Hare Rat
Lyencephala Loose Brained		Marsupialia	Rhizophaga Poephaga Carpophaga Entomophaga	Wombat Kangaroo Phalanger Opossum
		Monotremata	Echidna Ornithorhynchus	Echidna Duck Mole

The characteristics that go with monotremes and marsupials connect them with the birds and reptiles on one side, and the mammals on the other. As shown in chapter 4, they are non-placental, a circumstance in which they are unlike all other mammals. The young are brought forth in a very immature state. The kangaroo mother conveys her young to her pouch with her lips; after a uterine period of 38 days they attach themselves to the teats, and there remain for eight months. The monotremes having no pouch leave their young in a nest, like the young of rats, &c. A young ornithorhynchus is from one to two inches long. Its tongue and lungs are well developed. But it is blind, and its horny bill is not developed, obviously to its advantage while it has to suck, especially as the mother has no projecting teats.

In the birds and reptiles the optic lobes are a single pair, and so they are in the monotremes amongst the mammals. But in the monotremes the valvula of vieussens becomes thickened at its anterior edge by the addition of transverse white fibres just back of the optic lobes. This swelling is the beginning of the second pair of optic bulbs, the testes. These become well developed in the marsupials, and occur in all the families above these, the whole four bulbs generally going under the

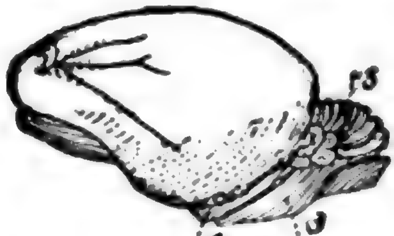


FIG. 302.

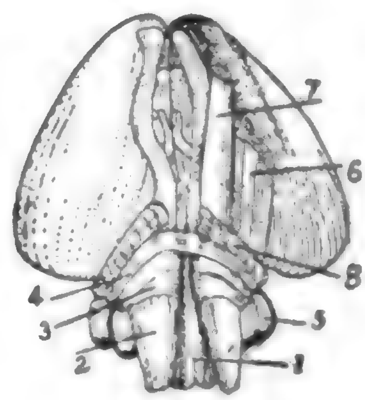


FIG. 303.

FIG. 302.—*Side view of Brain of Ornithorhynchus.*
FIG. 303.—*Bottom view.*
1.—Anterior pyramids.
2.—Olivary bodies.
3.—Corpora trapezoidea (Arciform fibres in man).
4.—Pons Varolii.
5.—Cerebellum.
6.—Two roots of the Trigeminal nerve (very large).
7.—Third branch of same.
8.—Ganglion in which it originates.

name of the corpora quadrigemina, the original pair being the nates, and the new pair the testes.

In birds the ventricle of the hemisphere, or lateral ventricle, is almost filled by the corpus striatum, and in them there is no hippocampus. In the mammals, however, the shell of the cerebrum begins to enlarge,

FIG. 304.—*Brain of Dasyure, or Native Devil* (a marsupial).
a.—Olfactory lobes. *c.*—Optic lobes.
b.—Cerebrum. *d.*—Cerebellum.
e.—Medulla oblongata.

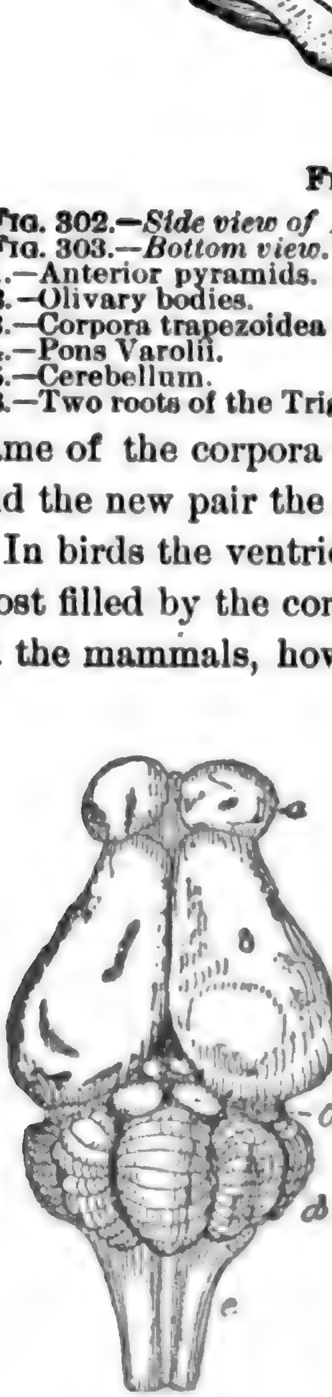


FIG. 304.

and in doing this commences to form itself into folds or convolutions. One of the first and most constant of these is a fold pushed into the ventricle from the inner margin of the temporal lobe, from the inside wall of each hemisphere, where the two abut against each other. This fold of brain matter pushed into the lateral ventricle is called the hippocampus, (hippocampus *major*, or cornu ammonis, in Man and the Quadrumana) and the crease formed on the external part of the inner face of the hemisphere, by the fold, is called the hippocampal fissure. Longitudinal fibres are developed in connection with the hippocampus, forming a band named the tænia hippocampi (or corpus fimbriatum in man). This band, starting at the pes hippocampi at the lower, or posterior, extremity of the ventricle, runs up to the roof of the ventricle and becomes the posterior pillar of the fornix. It then bends forward along

the roof of the ventricle, above the hippocampus, and converges toward its fellow from the other hemisphere. Their junction constitutes a union, or commissure, between the two hemispheres. Fibres are continued forward, radiating from this upon the inner or mesial surface of the forepart of the hemispheres, while others bend downward, forming the anterior pillars of the fornix. This common meeting ground constitutes the hippocampal commissure, and it forms the beginning of the great commissure, the corpus callosum. The two hippocampi are relatively very large in the echidna and the marsupials, and the hippocampal commissure connecting these becomes, therefore, a correspondingly important tie between the two hemispheres. This tie is, however, confined to the lower part of the cerebrum, the part above the ventricles not being directly joined together until the corpus callosum is formed, in the higher species, the marsupial being in this respect in the same condition as the monotremes and birds. The anterior commissure is large in marsupials and monotremes.

(The *anterior commissure* which appears to connect the two corpora striata, in reality does not. It is composed of two parts; the front part forms a connection between the olfactory tracts. This division of the commissure is especially large and well marked in animals with large olfactories, but is small in man and monkey. The posterior division of the commissure passes outwards, downwards and backwards, under the lenticular portion of the corpus striatum, and goes on to the hippocampal lobule and the nucleus amygdalæ, where its fibres spread out and terminate. It therefore connects the two opposite hippocampal lobules, &c.) (*Ferrier.*)

In the next advance of brain development, the corpus callosum is present. There is, however, but little advance in other respects, for the cerebral hemispheres show no other very marked superiority over those below. They are relatively larger, however, and grow over the optic lobes, and also partially conceal the olfactory lobes. The hemispheres are smooth, except a few of the highest in the sub-class. Owen names this sub-class the *Lissencephala.* The orders included in this sub-class are the Bruta, or Edentata, the Cheiroptera, Insectivora, and Rodentia. These animals still possess some of the characteristics of birds and reptiles. For example, the three-toed Sloth has cloaca, convoluted trachea, supernumerary cervical vertebræ, and floating ribs.[1] The Ant-eaters have long, slender, beak-like, toothless jaws, and a gizzard. The Pangolins (Manis), of Hindostan and Africa, (Edentula of the order Bruta) have both gizzard and gastric glands, like those of the birds, and have imbricated (or guttered) scales, and they are also toothless. The Armadillos have plates on their back, like the scaly lizzards.

[1] Almost all mammals have seven cervical vertebræ.

The Dormouse and Beaver have the "proventriculus," a little stomach, which, in birds, is at the lower end of the gullet above the gizzard, and is furnished with the gastric glands. The Porcupine and Hedgehog have quills. The Rodentia often have disproportionately developed hind limbs, like the birds. In the Jerboa the three chief metatarsal bones are fused into one, as in the birds. The Bat has wings, and a keel on the breast bone, as have the birds. The Cheiroptera, Insectivora, and some of the Rodents, are apt, like the Reptiles, to fall into a

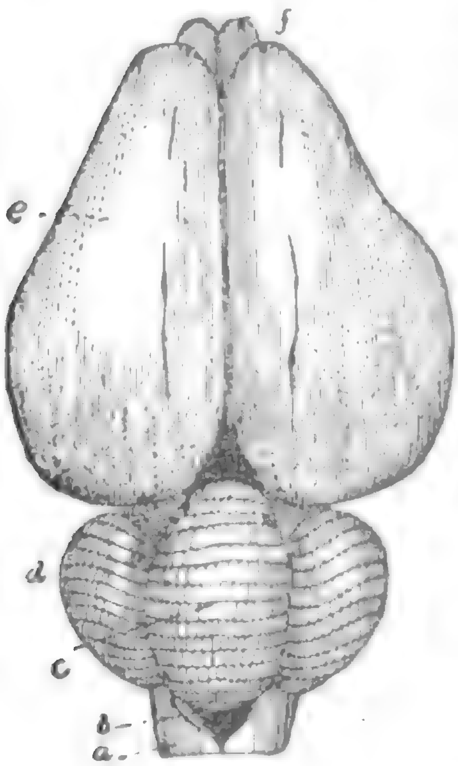


Fig. 305.

Fig. 305.—*Brain of Agouti, a South American animal resembling a Hare, but larger.*
a.—Medulla oblongata.
b.—Fourth ventricle.
c.—Middle lobe of Cerebellum.
d.—Lateral lobes of "
e.—Hemispheres of cerebrum (without convolutions).
f.—Olfactory lobes. (*Owen.*)

state of torpidity, accompanied by the circulation of black, or carbonized, blood. The Zizil (Arctomys citillus) has a temperature in summer of 103°. When torpid, it is reduced to 80° or 84°. The blood of the Marmot (Arctomys Marmota) is in summer 101°, and when torpid only 43° F. In the Lissencephala the reproductive testes remain in the abdomen or are protruded into a temporary scrotum only at the breeding period to be again retracted. In many of them the squamosal and tympanic plates of the skull bones retain their primitive condition of distinct bones. The orbits have not an entire rim of bone. There are two precaval (vena cavæ superior) veins, as in birds. (See fig. 116.)

In all the mammals above the marsupials, the corpus callosum is found more or less complete, its degree of development being indicated by its length from front to rear of the cerebrum, and the amount of the inferior deflection of its posterior and anterior extremities called knees. It is formed by the gradual increase of the transverse fibres, which, originally passing over the hippocampal commissure, receive additions to their number at the forward or anterior edge of the *lyra*, which is the name given to this body of fibres. The effect of this is to push upward and backward the original cross-fibres uniting the hippocampi, until from a position well in advance, they are crowded back, always forming the rear end of the corpus callosum. With the increase of the corpus callosum there is a corresponding decrease in the size of the anterior commissure.

The development of the hippocampus major and the accompanying commissures, the longitudinal fornix and the transverse corpus callosum,

creates a series of very important distinctions from the brains of birds and reptiles. Since mammals have certainly been developed from reptiles, it is evident that the steps by which the remarkable transition was made, were through animals now extinct. It will probably never be possible to trace these with certainty, since the structure of the brain could never be preserved fossil. Owen observes that if we could examine the brains of the *Dinosaurs* we might find the intermediate structures. This is very likely. These animals belonged to the Mesozoic era. (See page 88.) They were reptiles of immense size, and possessed many mammalian characteristics. The long bones have a medullary cavity; the feet are short and, with the exception of the hoofed toes, like those of pachyderms; the sacrum consists of at least *five* united vertebræ; the lower jaw, in some species, has lateral motion for trituration. (Dana.)

The corpus callosum, then, is fairly inaugurated in the Rodents, Insectivores, and others of the Lissencephala. In these animals a commencement of the septum lucidum, or wall between the anterior parts of the lateral ventricles, is introduced also. It is not, however, completed in this sub-class, but remains elementary. In these animals the hippocampi and the optic lobes are proportionally large; the front ones, the nates, being larger than the testes. The corpus striatum is small. The orbits of rodents are not separated from the temporal fossa, except in the cheiromys (the aye aye). The eyes are therefore in the brain case. Behind the posterior margin of the pons varolii, on the ventral face of the medulla oblongata, there is, in most of the mammals, a body of cross fibres on each side, occupying a rectangular area, and named, from its shape, the corpus trapezoides. They are well defined in the ornithorhynchus (fig. 302) and in the rabbit; diminish in the pig and other gyrencephala, and are wanting in the apes and man, their function being performed by the "arciform fibres" described in chapter 57, which are the homologues and derivatives of the trapezoidea. The vermis, or vermiform process, the median lobe of the cerebellum, constitutes the whole cerebellum in the Fishes, Birds and Reptiles. In mammals it is flanked and reinforced by side lobes. (fig. 305, *d.*) Relative to these, it is large in the lower mammals but decreases in size as we ascend the scale. In the ape and man it is proportionally much reduced, and is almost entirely concealed by the overgrowth of. the lateral lobes.

The highest of the mammal races, excluding man, are designated, under Owen's brain classification, as the Gyrencephala, the name signifying "convoluted brain." It is descriptive of most of the brains in this sub-class; a few, however, of the smaller members of it have smooth cerebrums. In the animals of this class, excepting the cetacea and the elephant, the reproductive testes are in an external scrotum. Except-

ing in the case of the elephant, the right and left descending veins are united into one before discharging into the right auricle. The gyrencephalic brain is usually accompanied by a better physical development, either greater size, or strength, or activity. The smaller members of each family are apt to possess less highly developed cerebrums than those of the larger members. The difference in the activities of the mammal cerebrum is indicated by the convolutions and fissures. By the help of the figures of convolutions, for which we are chiefly indebted to Owen, comparison can be easily made. The first fissure developed on the outer surface of the cerebrum is the great longitudinal fissure which separates the two hemispheres. This fissure is found in all the vertebrates except some of the fishes. It is not equally complete in all.

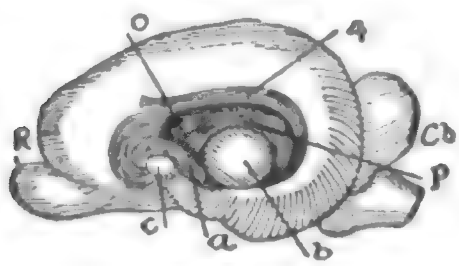


FIG. 306.

FIG. 306.—*Inner surface of hemisphere of Brain of Ornithorhynchus.*
R.—Olfactory lobe.
Cb.—Cerebellum.
a.—Anterior pillars of the fornix.
o.—Commissure of the pillars of the Fornix [(Lyra).
p.—Posterior pillars of the Fornix.
4.—Hippocampal fissure.
c.—Anterior commissure of the brain.

In the ornithorhynchus there is formed for the first time the hippocampal fissure, No. 4, which is formed by the pushing in of the hippocampus from the inner, or mesial, surface of the hemisphere. Aside from this, there is little or no break in the smoothness of the cerebrum. The brain of the echidna is considerably convoluted. Of the regular convolutions found in the higher families he has beside No. 4, the super callosal No. 7'. Most of the others remain unidentified with those of the gyrencephala. They are mostly transverse.

Names of the fissures numbered in the figs. of cerebral convolutions.

1	Interhemispherical.	9'	Subsylvian.	16''	Entorbital.
2	Ectorhinal.	10	Medilateral.	16'''	Ectorbital.
2'	Basirhinal.	11	Lateral.	16*	Antorbital.
3	Entorhinal.	12	Coronal.	17	Occipital.
4	Hippocampal.	13	Lambdoidal.	17'	Superoccipital.
4'	Posthippocampal.	13'	Entolambdoidal.	17''	Entoccipital.
5	Sylvian.	14	Frontal or postfrontal.	17'''	Ectoccipital.
6	Marginal.	14'	Superfrontal.	17*	Postoccipital.
6'	Postmarginal.	14''	Midfrontal.	18	Tentorial.
6''	Premarginal.	14'''	Subfrontal.	18'	Entotentorial.
7	Callosal.	14*	Ectofrontal.	18''	Ectotentorial.
7'	Supercallosal.	15	Falchial.	19	Septal.
8	Supersylvian.	15'	Subfalchial.	19'	Superseptal.
8'	Ectosylvian.	16	Orbital or postorbital.	19''	Subseptal.
9	Postsylvian.	16'	Midorbital.	19'''	Postseptal.

Names of the folds as lettered on the figures.

a	Hippocampal.	*l*	Medial.	*q*	Occipital.
a'	Posthippocampal.	*m*	Medilateral.	*q'*	Midoccipital.
b	Basirhinal.	*n*	Frontal.	*q''*	Suroccipital.
c	Entorhinal.	*n'*	Superfrontal.	*q'''*	Suboccipital.
d	Ectorhinal.	*n''*	Midfrontal.	*q**	Postoccipital.
e	Sylvian.	*n'''*	Subfrontal.	*r*	Tentorial.
e'	Presylvian.	*n**	Ectofrontal.	*r'*	Entotentorial.
f	Postsylvian.	*n***	Prefrontal.	*r''*	Ectotentorial.
f'	Subsylvian.	*o*	Postorbital.	*s*	Septal.
f''	Entosylvian.	*o'*	Midorbital.	*s'*	Superseptal.
g	Supersylvian.	*o''*	Entorbital.	*s''*	Subseptal.
h	Marginal.	*o'''*	Ectorbital.	*s'''*	Postseptal.
h'	Postmarginal.	*o**	Antorbital.	*t*	Falchial.
k	Callosal.	*p*	Lambdoidal.	*t'*	Subfalchial.
k'	Supercallosal.	*p'*	Entolambdoidal.		

The marsupials add the ectorhinal No. 2 and the sylvian fissure No. 5. In some are also found Nos. 8, 9, 10 and 12, not all well developed, however. (See fig. 307.) In the smaller species of the carnivores, there are to be found Nos. 2, 5, 8 and 14 on the outside, and on the mesial face are the hippocampal No. 4, and the callosal No. 7. In some

Fig. 307.—*Top view of Brain of Kangaroo (Macropus Major).*

of the larger genera are to be found in addition the post sylvian No. 9, the lateral 11, and the coronal 12. The brain of the seal is one of the most highly developed among the carnivores. The part behind the fissure of sylvius is well developed, and covers more of the cerebellum than is covered in the other carnivora. The large fissures, 8 and 11, divide the principal part of the top surface of the hemisphere into three grand divisions, marked *e*, *g*, *l*, and named the sylvian, supersylvian, and medial folds.

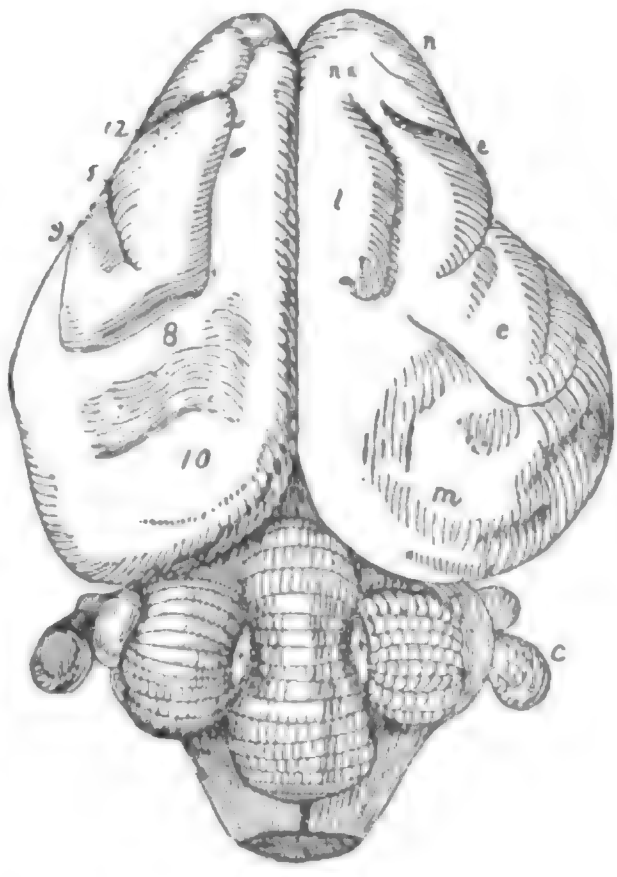


Fig. 307.

Besides these there are numerous small fissures subdividing the cortex into many minor folds.

The cetacea possess a high development of brain, and the dolphins preserve a resemblance to the seal in the three great longitudinal folds,

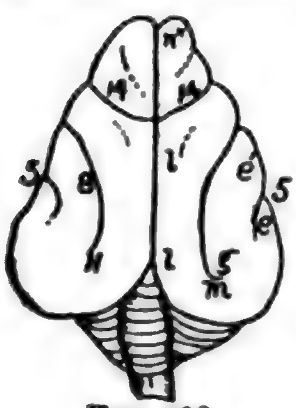


Fig. 308.

Fig. 309.

Fig. 310.

Fig. 308.—*Top view of Brain of Stoat. (Putorius.)*
Fig. 309.—*Top of Right hemisphere of Coati.*
Fig. 310.—*Same of Fox.*

e, *g*, *l*. These, however, are so intersected by minor fissures that dissection is required for their identification; the cleft of the primary ones being deeper than that of the minor ones. Fig. 316 shows lateral ventricle of the dolphin with its beginning of a posterior

cornu now seen for the first time in the ascending animal scale.

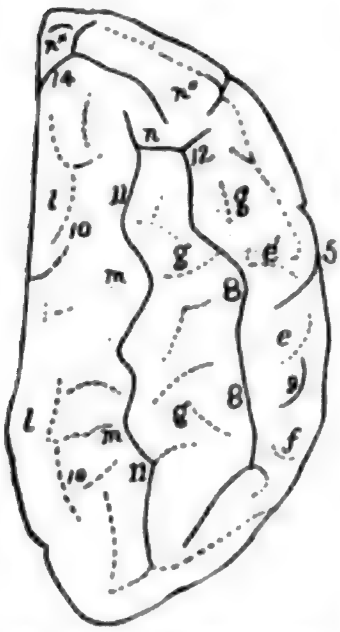


FIG. 311.—*Top view of Right half of Brain of Seal.*

Turning now to the ungulates, or hoofed animals, horse, stag, giraffe, &c., we find the pattern somewhat changed, and one or two significant additions to the convolutions. Fissures 4, 7, 7′, 2, 5, 8, 9, 11, 12, 14, are tolerably constant and common to this group as well as to the carnivores. The direction those take which lie on the top and sides of the hemispheres, is, in the ungulates generally, a diagonal one from behind, forward and inward, while in the carnivores it is more nearly parallel with the longitudinal axis of the brain. In the ungulates fissure 11 appears to be crowded outwards, and two additional fissures inserted between it and the mesial face of the hemisphere. These are the medilateral 10, and the lambdoidal 13. There appears to be a slight intimation of the beginning of 13 in the cat. This fissure in man and the apes is reckoned to be the anterior boundary of the posterior lobe. If so, the ungulates must have the posterior lobe in process of development. It is remarkable that two diverging branches of the mammal class should, as they

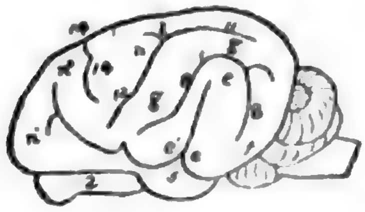


FIG. 312.

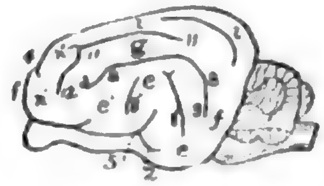


FIG. 313.

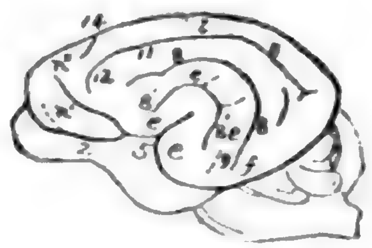


FIG. 314.

FIGS. 312, 313, 314.—*Side view of brains of Coati, Cat and Fox.* (*Owen.*)

FIG. 315.—*Inner surface of hemisphere of Cat.*

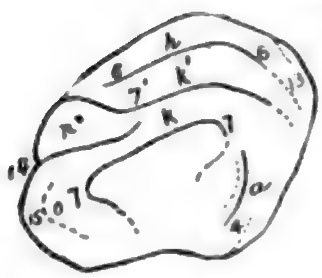


FIG. 315.

spread apart take on the same processes of brain development, even to details as minute as the general convolutions.

The posterior lobe hinted at in the carnivora, fairly begun in the ungulates, is fully completed in the apes and man. These animals still possess the principal fissures and convolutions of the ungulates, as will be observed by comparing the figures. But there is a remarkable alteration in the direction taken by those in the upper posterior part of the cerebrum. The enormous growth of the convolutions marked p, q, q', &c., has had the effect to gyrate the posterior ends of fissures 8, 11, 10 and 13 outwards, their anterior ends remaining more or less fixed as pivotal points, as in No. 13, fig. 320. (*Cervus.*) The same thing has happened, to a certain extent, in the anterior lobe, the great growth of which has pushed back the outer

extremity of the coronal fissure No. 12, making it almost transverse instead of longitudinal, as seen in the carnivores and some of the ungulates, figs. 313, 323, &c. The mastoid, or middle lobe, of the ungulates

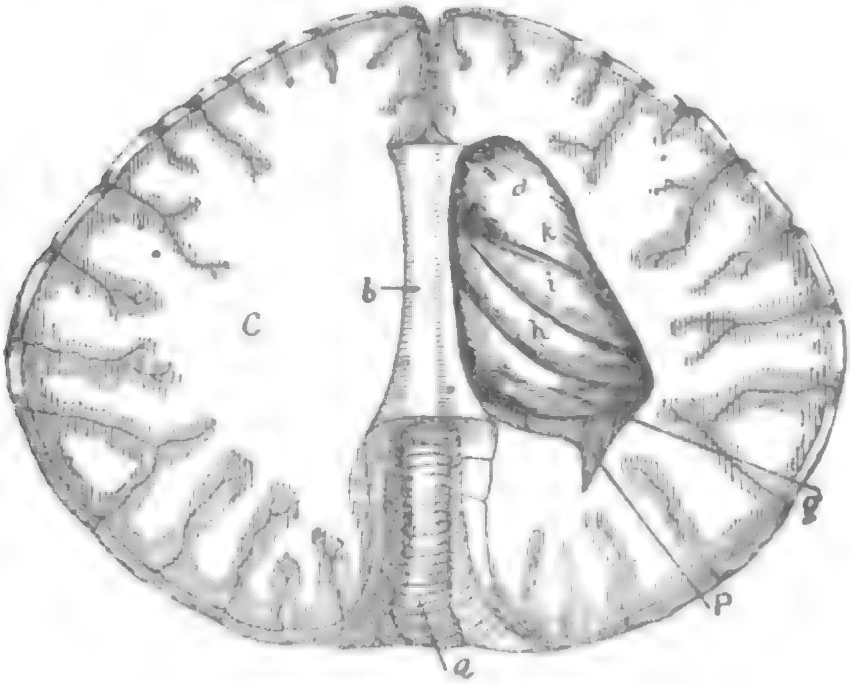


FIG. 316.

FIG. 316.—*Horizontal section of the Brain of the Dolphin.*

a.—Vermiform process, or middle lobe of the Cerebellum.
b.—Corpus Callosum.
c.—White fibrous matter.
d, k.—Corpus Striatum.
i.—Optic Thalamus.
g.—Hippocampus Major.
h.—Tænia Hippocampus (unusually broad).
p.—*Posterior Cornu.*

(*Good's Book of Nature.*)

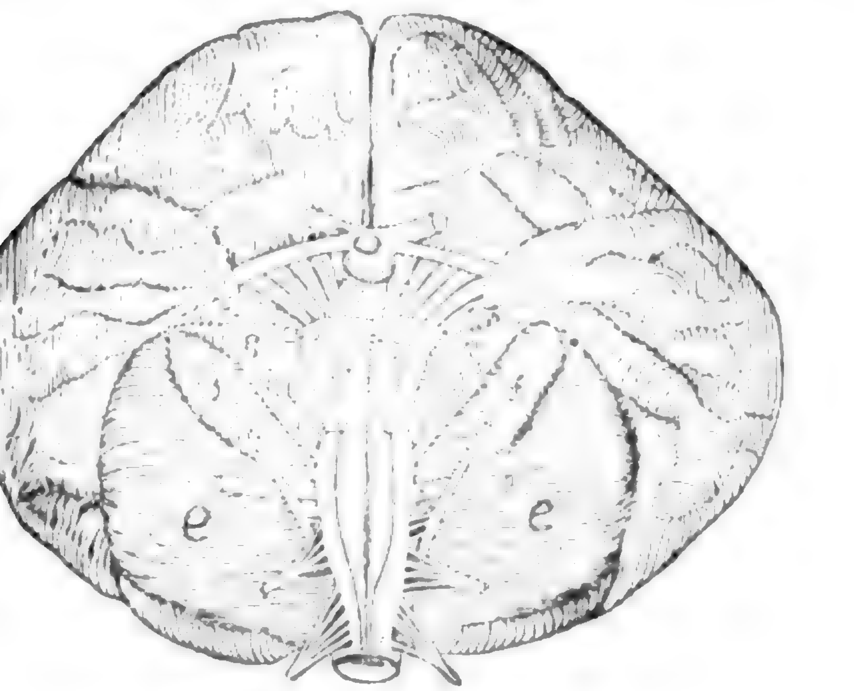


FIG. 317.

FIG. 317.—*Base of Brain of Dolphin (Delphinus Delphis.)* (Owen.)

e.—Lateral lobes of Cerebellum (very large in Cetacea).
f.—Oblique lobule or Amygdaloid lobe.
h. Floccus of Reil—origin of Auditory nerve.

is thus, in these animals, thrown from a diagonal to a nearly transverse position between the coronal fissure 12 as its anterior boundary, and the lambdoidal 13 as its posterior limit. In the quadrumana, as in the other orders of the gyrencephala, the smallest members have brains al-

most destitute of convolutions. The little midas, or marmoset platyrrhine, has only one fissure on the outside, No. 5, the sylvian, although it possesses both the hippocampal and posthippocampal (4 and 4′) on

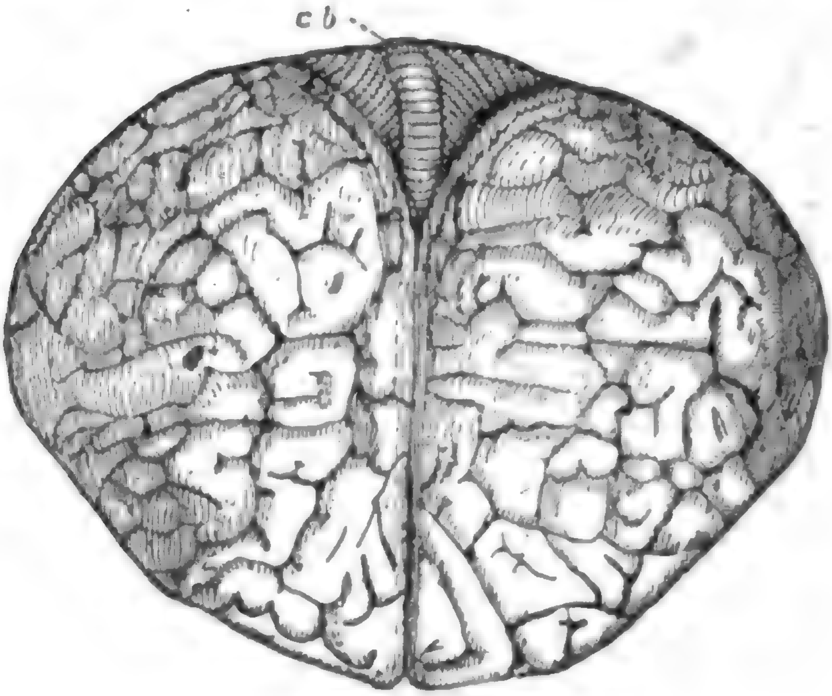


FIG. 318.—*Top view of Brain of Dolphin.*

the septal, or mesial surface, these being the fissures over which are folded the hippocampus major and hippocampus minor, respectively. In the callithrix, another platyrrhine (fig. 330), several additional fissures are to be observed, and it is to be noted that these are of the lon-

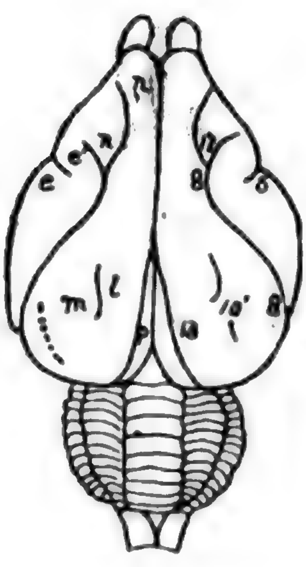


FIG. 319.

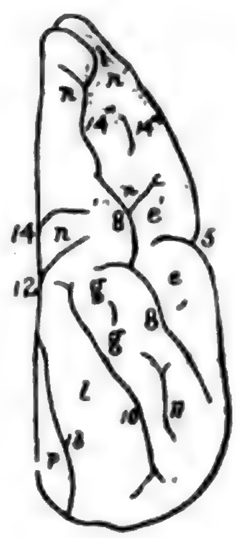


FIG. 320.

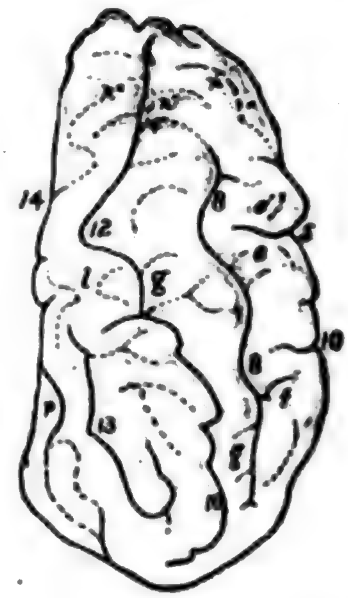


FIG. 321.

FIG. 319.—*Top of Brain of Tragulus, or Chevrotain, the smallest of Antelopes.*
FIG. 320.—Top of right half of cerebrum of Stag.
FIG. 321.—Same of Giraffe. (Hoofed mammals.)

gitudinal sort, like the carnivores. In the macacus (fig. 330), another platyrrhine, and the chimpanzee, a catarrhine ape, the fissures take on the transverse position substantially, as in man.

The division of the brain into three lobes appears the most natural, making fissures 12 and 13 the boundaries; but some anatomists count

five in man, some of them more or less artificial. A part sometimes called the central lobe is the Island of Reil, situated inside of the fissure of sylvius. It is the organ of speech. In the Dog, the part an-

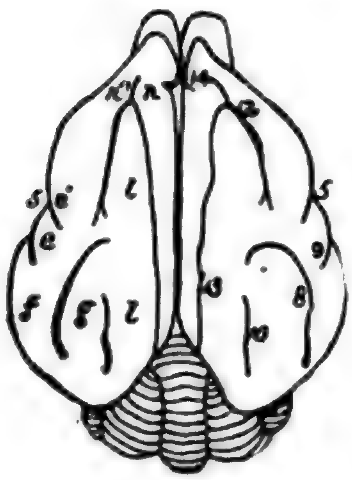


FIG. 322.

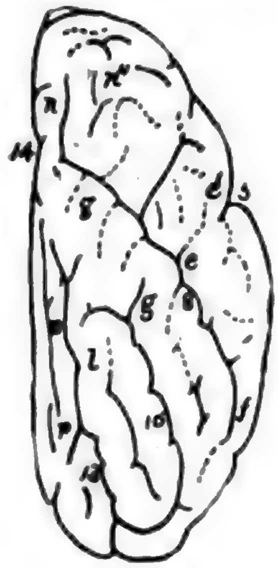


FIG. 323.

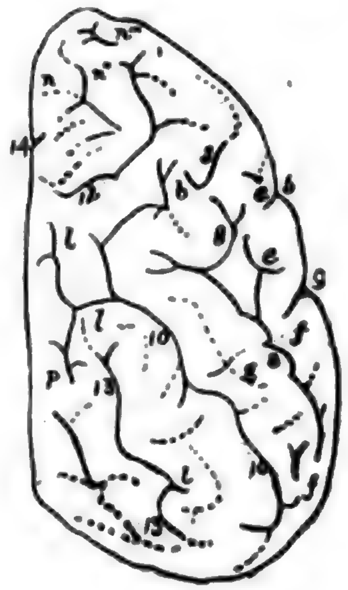


FIG. 324.

FIG. 322.—*Top view of Brain of the* Rock Coney; *Hyrax.*
FIG. 323.—Top view of right hemisphere of Horse.
FIG. 324.—Same of Rhinoceros. (Hoofed.)

swering to the Island of Reil is quite smooth, and the fissure of sylvius is short, not extending over half way to the median or interhemispherical fissure. The Island is, however, convoluted in the Porpoise and in the Apes as well as in Man.

FIG. 325.

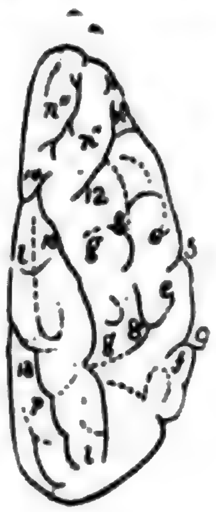


FIG. 326.

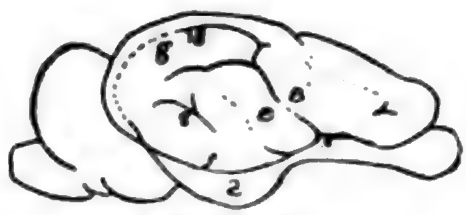


FIG. 327.

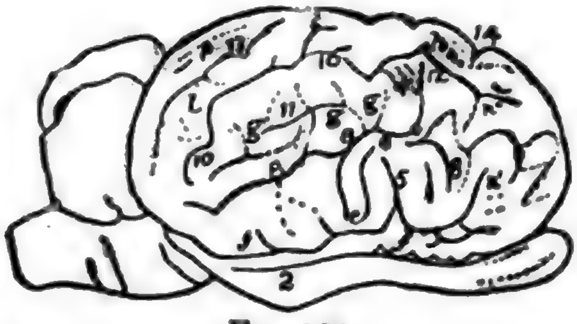


FIG. 328.

FIG. 325.—*Top of right hemisphere of Pig* (*Sus*).
FIG. 326.—*Same of Lama* (*Auchenia*).
FIG. 327.—*Right side Brain of Rock Cony* (*Hyrax*).
FIG. 328.—*Same of Giraffe.*

The human brain in its development passes through stages similar to conditions which are permanent in the quadrumana, as regards the convolutions. (Owen.) In the brain of a fœtus of three months, the fissures 4, 7, 2, 5, 13′, 9 and 12 are already indicated, or more or less developed, and it may be compared with the brain of the cebus. At seven months the human fœtus presents a striking agreement in the de-

velopment of the convolutions with the catarrhine apes. In those animals which have the greatest number of convolutions, there is a greater or less want of symmetry between the two hemispheres. In general terms, the fewer convolutions, the greater the symmetry. Thus the cat

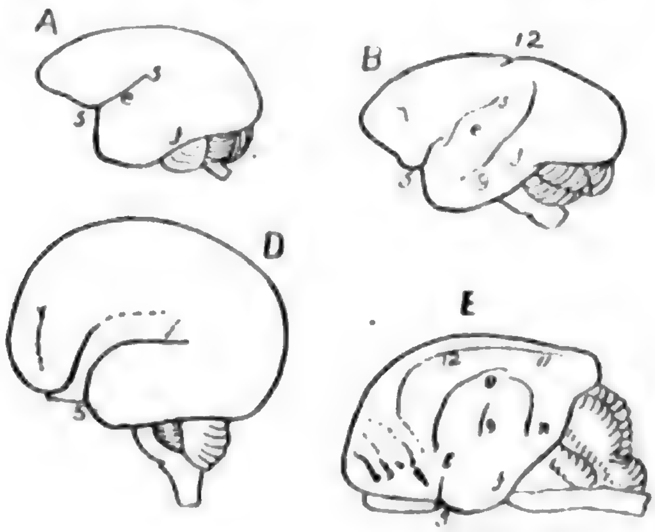


FIG. 329.

FIG. 329.—*External surface of left hemisphere of*
A.—Midas. C.—Gibbon. E.—Aye-Aye.
B.—Callithrix. D.—Human fœtus (5 mo.). F.—Macacus.

and fox have comparatively few convolutions, and are quite symmetrical as compared with the horse, the dolphin, the ape, or man.

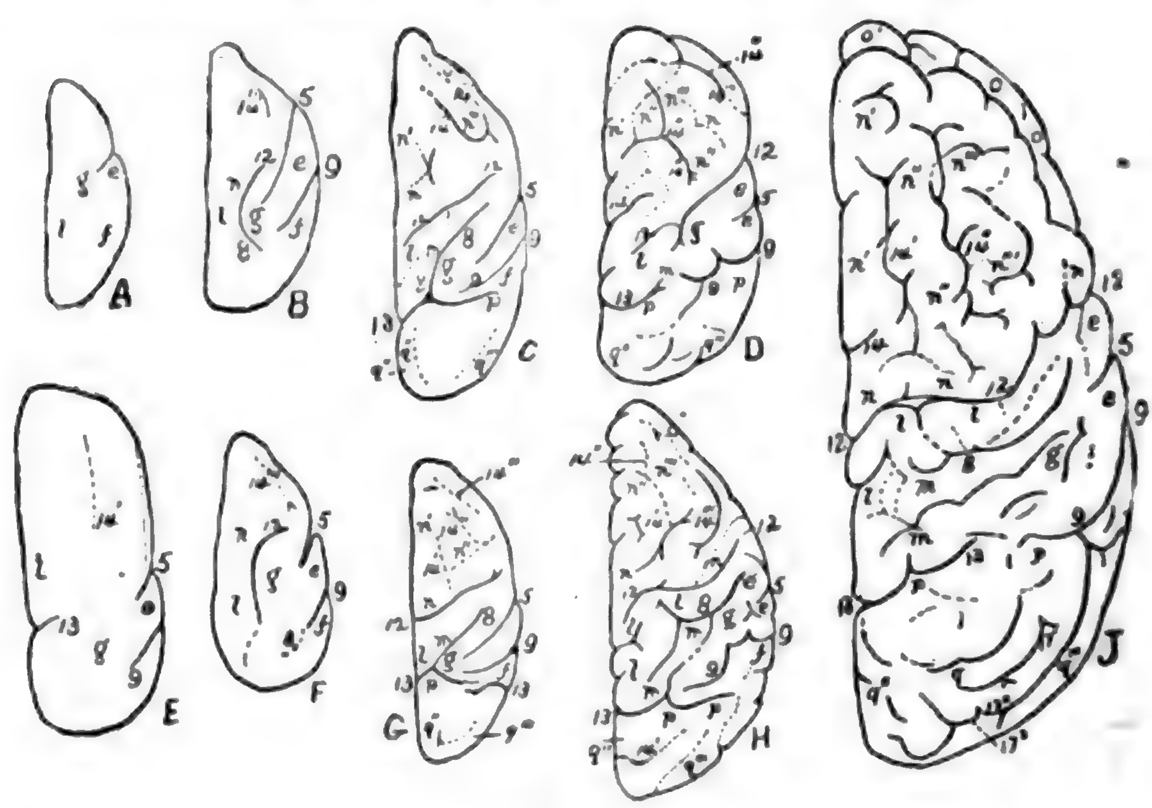


FIG. 330.

FIG. 330.—*Convolutions of Brains of Monkeys, Apes and Man.*
A.—Midas. C.—Macacus. E.—Human fœtus, 3 mo. G.—Cebus.
B.—Callithrix. D.—Human fœtus, 7 mo. F.—Lemur. H.—Chimpanzee.
J.—Adult Man. (*Owen.*)

Owen places man in a separate sub-class, which he calls Archencephala, or "governing brain." If man's works are to be regarded as a criterion by which to judge the quality of his brain, this class distinction is justifiable. But, as Cuvier long ago observed, man's pre-eminence is due not so much to his individual superiority as to his faculty of com-

bination for mutual assistance and information, an advantage due almost, if not quite, exclusively to the faculty of speech. A bachelor ape, driven away from his family and community, will live alone for years with no other weapons than stones and clubs. Deprive a man of all knowledge of the appliances and inventions made by his fellows, and

FIG. 331.—*Inner surface of cerebral hemisphere of Aye-Aye.* (*Monkey.*)

FIG. 332.—*Inner or septal (mesial) surface of the posterior lobe of the Human Cerebrum.*

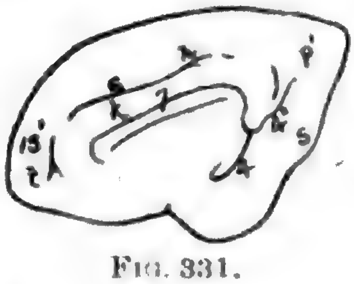


FIG. 331.

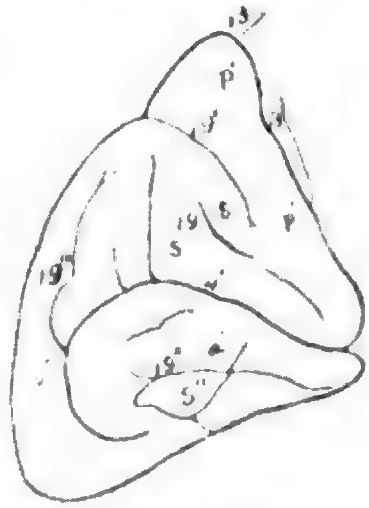


FIG. 332.

turn him out into the wilderness to shift for himself, and he would succeed no better than an ape, probably not so well. But by reason of the faculty of speech, the brain of every man is stored with the knowledge of the doings and discoveries of his fellows, near and far away, of the present time and of times long since passed away. The brain of an average educated man in civilized life, is reinforced by a hundred, a thousand or a million others. And what his brain cannot hold of the memories of the discoveries of the others, he can pack away in a library convenient and accessible whenever wanted. The aggregate

FIG. 333.—*Under surface of left half of Brain of Macacus (Ape).*
FIG. 334.—*Same in Man.*

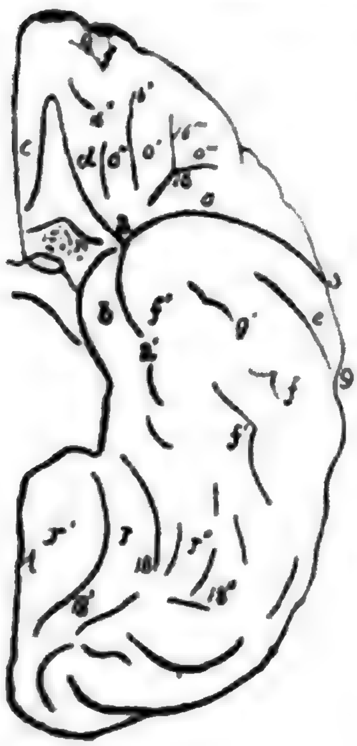


FIG. 333.

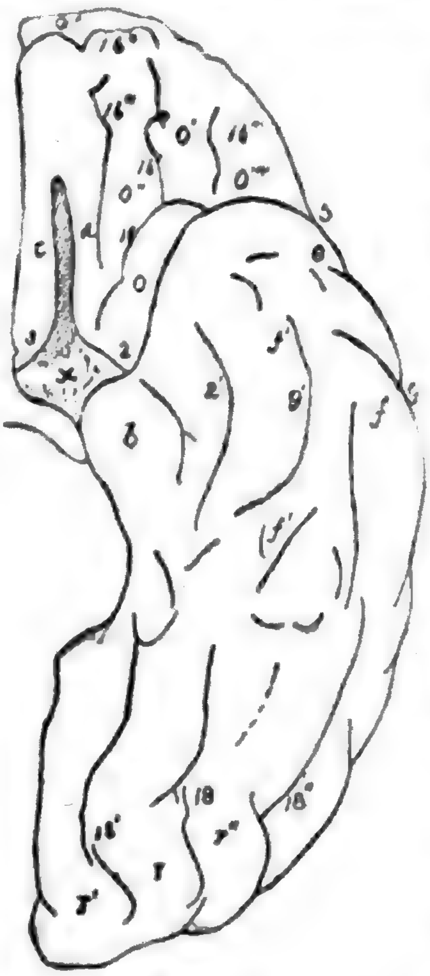


FIG. 334.

of human discovery is enormous and overwhelming. The addition made to the general stock by anyone is infinitesimal. But a cerebrum stored with memories is not entitled to a separate classification any more than an ear that has listened to the symphonies of a master, or a leg that has gyrated in the maze of a complicated dance.

Among the "gyrencephala" we find the ape and the hog, between the structure of whose brains there is a far greater difference than between the ape and man. Compare cerebrum of the pig, fig. 341, with that of

the chimpanzee, and we find the latter, relatively to the other parts, far the larger. Owing to the great development of the anterior and posterior lobes, it entirely covers up the cerebellum behind and the olfactory lobes in front. The convolutions are also far more numerous and complex. Beside these features of obvious distinction there are others

FIG. 335.—*Top of Brain of Lemur (Stenops Tardigradus).*
FIG. 336.—*Base of same.*

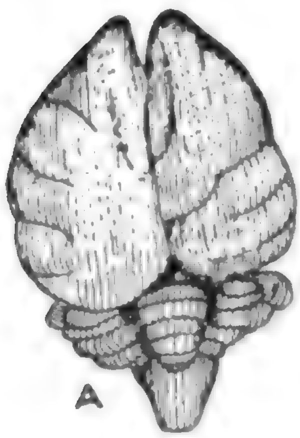


FIG. 335.

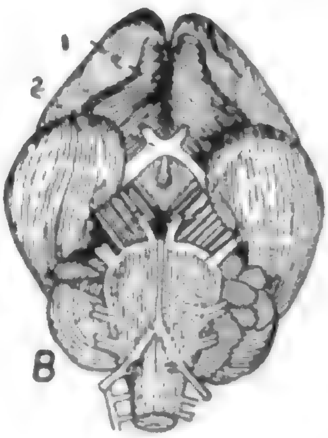


FIG. 336.

located internally. In the pig there is no posterior cornu of the lateral ventricle, and of course no hippocampus minor. In the chimpanzee there are both, and well developed. There are no other animals beside men and apes that possess anything like the posterior cornu, except the delphinidæ (or dolphin and porpoise family), which show a mere beginning of it. (Fig. 316.) If the brain of man is to be put into a separate sub-class from that of the pig, then is the ape entitled to the same distinction. The Rabbit is placed in the sub-class below the Pig,

FIG. 337.—*Base of Brain of Ourang Outang.*
1.—Olfactory nerve.
2.—Optic nerve and chiasm.
3.—Pons Varolii.
4.—Medulla oblongata.
5.—Cerebellum.
O.—Post orbital convolution covering Island of Reil in part.
O'.—Mid-orbital Convolution.
O''.—Ent-orbital "
O'''.—Ect-orbital "

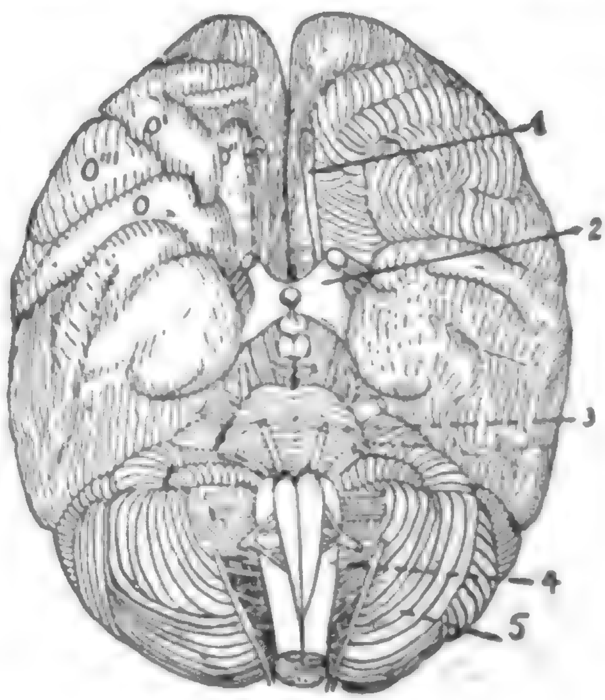


FIG. 337.

but the difference between their brains is less than that between the Pig and the Ape. The bodily structure of the man-like Ape also separates him from the other animals of the sub-class gyrencephala, and connects him with man. (See Chap. 2.) Whatever line of distinction is drawn between man and the higher apes on account of brain, it is equally proper to draw between the highest and lowest families of the quadrumana. The brain of the Lemur, fig. 335, presents more points of anatomical inferiority to that of the Chimpanzee or Gorilla than theirs do to Man's. The cerebrum does not nearly cover the cerebellum; the convolutions are not numerous; the lateral lobes of the cerebellum are not relatively well developed,

while the posterior lobe of the cerebrum and its contained posterior cornu and hippocampus minor are more or less rudimentary. In all the other Apes, Marmosets and Baboons, these parts are all well developed,

FIG. 338.—*Vertical middle section of Brain of Orang Outang* × ½.
1.—Superior longitudinal commissure.
2.—Corpus Callosum.
3.—Septum Lucidum.
4.—Fornix.
5.—Optic Thalamus.
6.—Pituitary gland.
7.—Corpora Quadrigemina.
8.—Crura Cerebri.
9.—Cerebellum. (*Vrolik.*)

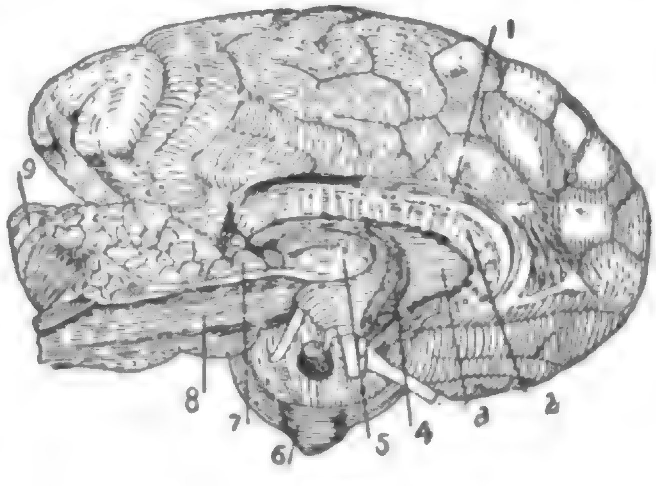


FIG. 338.

and in some cases as well or better than in man. (*Huxley.*)

There is, in fact, in the Quadrumana alone sufficient difference in brain structure to split the family in two and put a part of it among the Lissencephala, alongside the rodents and insectivores, and promote the rest to a subclass separate from the Dog and the Pig, provided the development of convolutions is made the basis of the classification.

The average weight of brain to the body in fishes is as 1 to 3,000. In a Chub (Luciscus Cyprinus) weighing 842 scruples, the brain, exclusive of olfactory lobes, weighed one scruple. In a Carp (Cyprinus Carpio) of 11,280 grains weight, the brain weighed 14 grains. In a Lamprey of 750 grains the brain weighed half a grain. The brain of the fish attains its mature size before the rest of the body. In the Newt weighing 39 grains, the brain weighs one-seventh of a grain, and in the Sirens, Amphiumes and Menapomes the proportion of the brain to the body is less than in the case of the Newt. The average weight of the brain to the whole body in the mammalia is said to be as 1 to 186, that of birds as 1 to 212, reptiles, 1 to 1321, fishes, 1 to 5668. But there are great differences between the different members of the classes. Thus the Blue-headed Tit has a brain one-twelfth as heavy as its body, or three times as heavy as man's brain relatively. The brain of the Goldfinch is to his body as 1 to 24, that of the field Mouse, a mammal, as 1 to 31. The relatively large brain of these animals is probably due

FIG. 339.—*Upper surface of Brain of Orang Outang.* (*After Sandifort.*)

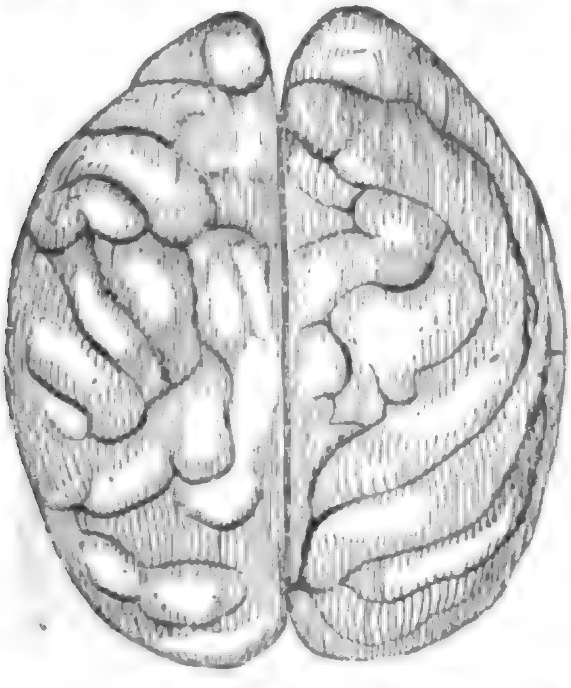
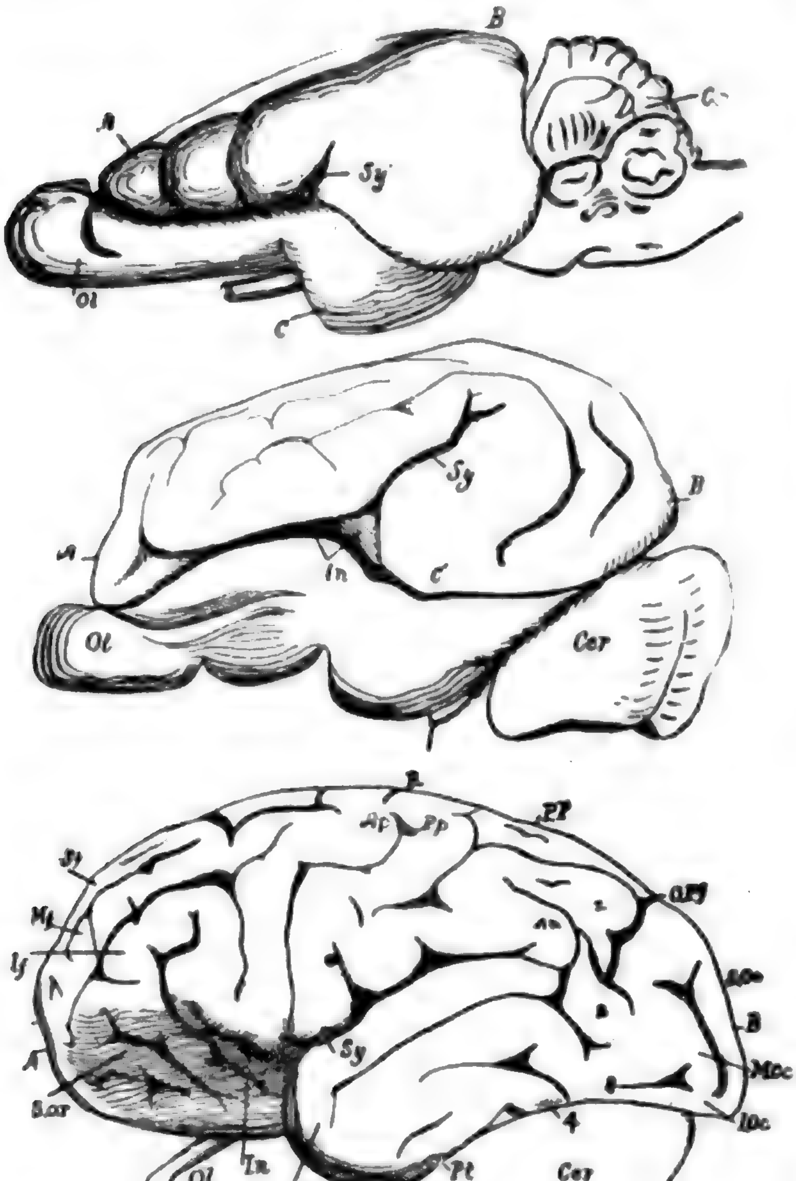


FIG. 339.

to the larger sensory and other ganglia rather than to the cerebrum. (*Carpenter.*) The brain is relatively larger in small or dwarfish animals than in large ones; just as it is in the same individual, larger relatively in infancy than in maturity. In the Flying Opossum (Petaurus), a marsupial, the brain is to the body as 1 to 25. In the large marsupial Kangaroo it is as 1 to 800. In the Harvest Mouse it is 1 to 20, while in the Capybara it is 1 to 300. In the Two-toed Ant-eater it is 1 to 60, while in the Great Ant-eater it is 1 to 500. In the Porpoise four feet long it weighs one pound, but in the Whale 100 feet long and 600 times heavier, the brain weighs not more than four times as much, or 4 pounds. In the Chevrotain (Tragulus pygmeus), a pigmy artiodactyle, the brain to the body is as 1 to 80, in the Giraffe as 1 to 800. In the Perissodactyle, little Hyrax, it is as 1 to 95, in the Rhinoceros, 1 to 764. In the carnivore Weasel it is as 1 to 90; in the Grizzly Bear, 1 to 500. In quadrumana, in the Midas, a Marmoset, it is as 1 to 20; in Gorilla, 1 to 200. (*Owen.*) The large animals appear to lose in weight of brain relatively to the small animals of the same families; but they gain in its structure. Thus the brain of the Gorilla is possessed of convolutions which are absent in the Midas. The brain of the Kangaroo is superior to that of the Petaurus, or flying opossum, in convolutions and in the quantity of gray matter in the cortex.

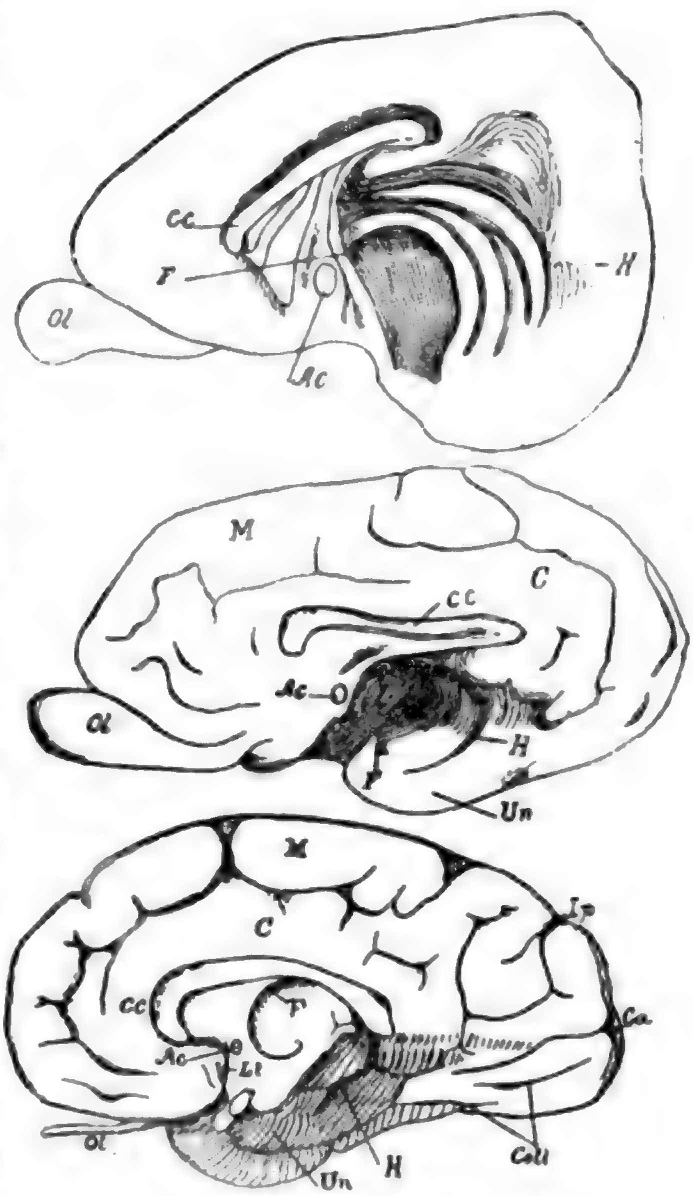


Figs. 340, 341, 342.

Figs. 340, 341, 342.—*External surface of Brain of Rabbit* (top fig.). *Pig* (middle fig.). *Chimpanzee* (bottom fig.).
Ol. Olfactory lobe.
A. Frontal lobe.
B. Occipital lobe.
C. Temporal "
Sy. Sylvian fissure.
In. Island of Reil.
S. or. Supraorbital.
Sf. Mf. If. Superior, Middle and Frontal gyri.
Ap. Antero-Parietal gyrus.
Pp. Postero " "
R. Sulcus of Rolando.
PPl. Posteroparietal lobule.
OPf. External Perpendicular, or Occipito Temporal Sulcus.
An. Angular gyrus.
2, 3, 4. Annectent gyri.
At. Mt. Pt. Temporal gyrus.
SOc. MOc. IOc. Occipital gyrus.
Cer. Cerebellum.
(*Huxley.*)

The weight of the whole brain in adult man runs from 40 to 60 oz. In woman, from 36 to 50. The maximum of a healthy brain is about 64 oz., the minimum, 31 oz. Idiots sometimes run as low as 16 oz. In a brain weighing 51 oz., about the average of an adult male, the weights of the subdivisions would be about as follows: Cerebrum, $42\frac{1}{2}$ oz.; cerebellum, $5\frac{1}{4}$ oz.; medulla oblongata, optic thalami and corpora striata, altogether, $3\frac{1}{4}$ oz. The spinal cord would weigh about $1\frac{3}{4}$ oz. The brain equals about one thirty-seventh of the whole man. (*Carpenter.*)

Figs. 343, 344, 345.—*View of inner (mesial) surface of hemisphere of Rabbit (top fig.); Pig (middle); Chimpanzee (bottom fig.).*
Ol. Olfactory lobe.
cc. Corpus callosum.
Ac. Anterior commissure
H. Hippocampal sulcus.
Un. Uncinate gyrus.
M. Marginal "
C. Callosal "
Ip. Internal perpendicular.
Ca. Calcarine sulcus.
Coll. Collateral "
F. Fornix
Lt. Lamina terminalis. (*Huxley.*)



Figs. 343, 344, 345.

The average weight of a Horse's brain is 22.9 oz., and of the spinal cord 10.1 oz. The brain of the Ass weighs 12.7 oz., and the spinal cord 5.3 oz.; that of the Ox 16.9 oz., the spinal cord 7.8 oz.; that of the Sheep and Goat 4.6, and the spinal cord 1.8. The brain of the Pig weighs 5.6 oz., the spinal cord 2.4; that of the Dog 6.3, the spinal cord 1.2; that of the Cat 1.1 oz., and of the spinal cord 0.3 oz. The brain of the Chicken weighs 0.16 of an ounce, that of a large whale 80 oz., that of an elephant, 160 oz.

Nerves. In the Ornithorhynchus the olfactory nerve leaves the olfactory lobe on each side in a single bundle, and without dividing passes entire through the skull, as in Birds and Lizzards. In all the other mammals the trunk is subdivided into a greater or less number of nerves, each one passing through the skull by an orifice of its own. In the Echidna and the marsupials the number of nerves and the holes in the cribriform plate through which they pass is very great. The surface of pituitary membrane is also of great extent. In all the families between the Ornithorhynchus and the quadrumana, the number of the olfactory

nerves is large, except in the cetacea. In those having baleen they are few and small, but in the other cetacea there are none at all. Thus the Porpoise, which has a cerebrum highly convoluted, and furnished with a sylvian fissure, an elementary Isle of Reil, and an elementary posterior cornu, is nevertheless destitute of olfactory nerves. Its corpus callosum is not large, and the anterior commissure is reduced to a rudiment. Its ectorhinal and basirhinal tracts at the base of the cerebrum are still preserved. It is from the "basirhinal tract," which borders the outside of the mastoid lobe, that the external root of the stem of the olfactory lobe arises. The inner root, which is the shorter one, arises on the inner face of the hemisphere in front of the optic chiasm. The Hedgehog, among the insectivora, is remarkable for the number of its olfactory nerves. All the gyrencephala, except the quadrumana, possess them in large numbers. In quadrumana the olfactory lobe diminishes and the number of olfactory nerves decreases up to man, in whom the number is not often more than twenty; less relatively than the others possess.

As mentioned before, the optic nerves in man are made up of fibres from both the optic lobes, or corpora quadrigemina, and the optic thalami. Nevertheless it is shown that the corpora quadrigemina are the sole ganglions of the faculty of vision, and that the optic thalami are simply the organs for the condensation and transmission of the sight and other stimuli to the cerebrum. In animals with large eyes the optic nerve and the optic lobes are proportionally large, and vice versa, while no such correspondence is observed in the thalami. In Moles the eye, nerve and optic lobe are the smallest among the mammals. In the Giraffe they are the largest.

The most remarkable peculiarity of the optic nerves is their decussation, mention of which has been made. In the decussation of the optic nerves of mammals, all the fibres do not cross. As shown in fig. 346.

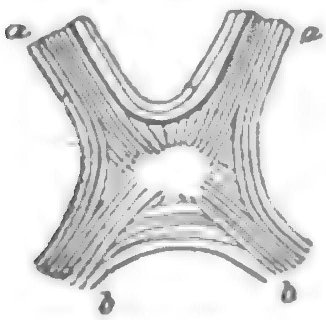


Fig. 346.

Fig. 346.—*Diagram of the optic chiasm.*
a, a.—Ends toward the eyes.
b, b.—Ends toward the brain.

the fibres from *b* divide; those on the outer side keeping on their own side, and going to the eye of the same side, the middle ones cross over, going to the opposite eye, while still others cross over both before and in the rear, forming a commissure. Those in the front commissure appear to connect the eyes without going to the brain, while those in the rear commissure connect the two halves of the brain without going to the eyes. The commissure fibres in front are not found in all mammals, but those in the rear are generally present in those above the rodents.

The optic nerve of mammals begins in the embryo as a flat strap, as

it is in the embryos of birds, reptiles and fishes. But while in these animals it becomes folded, or laminated, into a pile of plates, as in fig. 291, in man it is doubled over once, and its edges joined together to form a tube. There appear to be intermediate stages between these two forms. In cetacea the nerve is a cylinder in which longitudinal partitions are arranged converging toward the center, one edge being fastened to the external sheath, the whole thus forming a bunch of longitudinal triangular chambers. In others, the nerve is composed of longitudinal canals enclosed within the external sheath of dura mater. Either of these forms might result from the folding of the optic nerve of the fish into a cylinder, the circumference of which would retain longitudinal corrugations. Further modifications of these might convert them into tubules, or abolish them altogether, leaving the nerve a plain cylinder, as in man.

There is no decussation of the optic nerves in the case of the hags and lampreys, but each nerve connects only with the eye on its own side. In the fœtal development of the vertebrates it is the same; the nerve at first connecting the eye with the vesicles of the third ventricle on its own side; later, the nerve fibres gradually extend over to the opposite side of the brain and form the fusion with the opposite nerve. These facts are sufficient evidence that originally the nerve fibres did not cross, and that the habit was taken up, from some cause, by the ancestor, or ancestors, of the present races. That the process was gradual is also proved by comparative anatomy, because, in different animals there are different degrees of perfection in the chiasm. Thus it appears that in the Skate (fig. 285) the nerves are connected together by a commissure. In the teleostean fishes the nerves cross, but there is no commissure or mingling of the fibres. (See figs. 81 and 289.) In the mammals, however, there is both a crossing and a fusion. (Figs. 270, 317, 336, 337, &c.) If this decussation had not taken place the right eye would have been in connection with the left side of the body exclusively, because, on account of the decussation of the fibres of the spinal axis in the medulla oblongata, the right side of the brain, with which the right eye was first connected, is the organ of the left side of the body. It is obvious that while the right eye can help the left side, it is more effectual as a guide to the movements of the right side than of the left; and the left eye can better serve the left side than the right. Hence the economy of the crossing of optic nerves, by which each eye is put into connection with its own side of the body. That which is a real economy in the operation of natural energies, is in constant process of adoption in the organic world. The history of differentiation is a history of short cuts, and the elimination of indirect methods. The necessary tendency would be, in the case of the eyes, to rectify by a new decussa-

tion of the optic nerves, the disadvantage imposed upon them by the *first* decussation in the medulla oblongata.

The steps through which the second decussation have been brought about are undoubtedly repeated in the development of the embryo, but in the mammals and birds it is with such celerity, and is so much shortened that it appears not to have been traced. It is reasonable to suppose that in all cases in which there is decussation of the optic nerves there is also a decussation of fibres somewhere below the optic lobes. In the clupeidæ (Herring family) there is a decussation in the anterior pyramids of the medulla oblongata, followed by that of the optic nerves. It must be that this decussation in the medulla is of earlier origin than that of the optic nerves, and has, in fact, made the latter necessary. It is difficult to see how a bilateral body could be operated without nervous connections between the opposite sides, and there are such connections amongst all, even down to the worms. But such general crossing of fibres as takes place in the mammals, by which the chief, if not the entire, motor nerve service of one side of the body is furnished by the brain of the other side, must have originated from a state of things in which the chief activity of the body was transverse. All articulates possessed of jaws, work them by a lateral motion instead of a vertical one. It seems probable that the great crossing of nerves, together with that of muscles, originated in connection with these articulate jaws, and that the arrangement persisted after the original articulate throat ganglia had been supplemented by the great additions that gradually placed themselves in front of it, forming, in the vertebrates, the optic lobes, cerebrum, &c.

As to the principal cranial nerves they are generally homologous throughout the mammal class, and, to a greater or less degree, throughout the vertebrate sub-kingdom. The spinal nerves generally agree in number with the vertebræ, and are classified as the cervical, dorsal, lumbar, sacral and caudal. Those supplying the limbs are necessarily varied somewhat to suit the case, as in the Cetacea the nerves from the lumbar plexus cannot supply hind limbs as in the other mammals, since there are none. The anterior, or motor, part of the caudal nerves in cetacea, form a trunk to supply the strong muscles of the tail.

All the vertebrates above the Hags and Lampreys, have a sympathetic nerve system. Owen observes that as this sympathetic system begins in the myxinoids as an addition to an already existing cranio spinal system, it is to be regarded as a specialty of the vertebrate sub-kingdom, and as not having a counterpart in the nervous system of articulates. The semilunar ganglions and the solar plexus, which are the great centers of this system, where it is fully developed, are located in the positions in which the first development of the system is seen in the myxinoids and in the embryo of the higher vertebrates.

CHAPTER LIX.

FUNCTIONS OF THE SPINAL CORD.

Having, in the foregoing chapters, got some idea of the construction of the rather complicated machinery of brain and nerves through which the animal organism is regulated and directed, it will be our next endeavor to find out how this machinery works and what runs it.

There are several means by which the functions of the several parts of the brain and nervous centers are ascertained. One is by comparison of the human brain and nervous system with that of the lower animals, and by observing in connection therewith the contrasts and correspondences of nervous and mental action. Another is by experiments on the nervous system with direct stimuli. In the case of the lower animals these experiments are often accompanied by the artificial destruction of one part or another of the nervous apparatus, and observation made of the functions lost to the animal by such destruction. In man the same end is accomplished when accident or disease injures or destroys some function, which post-mortem examination subsequently connects with a lesion of some special part of the brain or nervous ganglia. In experimenting with animals it is practicable, in many cases, to cut away the cerebrum, or to sever the spinal cord at any point below the cervical vertebra without immediate destruction of life. Those lesions of the spinal cord which result in paralysis, amount temporarily to the same thing as the severing of the spinal cord. There have been numerous cases of this kind, from the observation of which it has been well settled that the spinal cord by itself possesses the necessary machinery for deflecting a stimulus from the environment back to the muscles of the limbs. And the cord being, for the time, practically disconnected from the parts of the upper nervous centers, which are the seat of sensation and consciousness, these reflected stimuli produce action in the limbs or muscles without its being felt or perceived by the patient, or in any way controllable by his will.

Carpenter cites a case of paraplegia, or paralysis of the lower half of the body, resulting from injury to the spinal cord in the dorsal region. The lower limbs had lost nearly all sensibility and power of voluntary motion. But when a limb was pinched or pricked, it jumped, the muscles being contracted so as to draw upward the toes and foot, bend the knee and raise the whole limb. These stimuli might be perceived by the patient, but if the sole of the foot were tickled by a feather, of which stimulus the patient might be unconscious, the convulsions would be still more violent, and of course uncontrollable. The

rectum and bladder being likewise out of reach of the voluntary ganglionic centers, their movements were subject only to the unrestrained stimulation which their contents naturally cause, and their evacuations were uncontrolled by the will, and accompanied by violent convulsions and spasmodic contractions of the organs. Another case is cited in which the injury was higher up, namely, at the lower part of the neck. The patient at first had no control of the lower limbs, trunk or hands, but a slight control of the wrists, a little more of the elbows, and still more of the shoulders, and there was a great reduction of the sensibility of the hands and feet. At first, tickling one sole caused reflex movement in that limb only; later, as recovery progressed, tickling one sole produced movements in both legs, and still later, on the 26th day after the hurt, such single stimulus caused movements not only in both legs but in the muscles of the trunk and arms as well. When the patient began to recover voluntary power over his muscles, so as to put his feet to the floor, the stimulation of their soles, caused by their contact with the floor, would instantly cause the bending of the knees. "On the 95th day this effect did not take place till the patient had made a few steps; the legs then had a tendency to bend up, a movement which he counteracted by rubbing the surface of the belly; this rubbing excited the *extensor* muscles to action, and the legs became extended with a jerk. A few more steps were then made, the maneuver was repeated, and so on." Recovery finally took place in both these cases. (Carpenter's Physiology.)

The action of the spinal cord when disconnected from the brain, is the same in the lower animals as in man, as has been shown by numerous experiments. If the proper part of the sensitive skin be excited, the stimulus is instantly reflected back to the limbs, causing their contraction. In experiments with a Salamander, in which the spinal cord had been cut in two, when the feet were irritated, especially by heat, convulsive movements were set up in the legs and tail. Yet it was proved that the animal possessed no sensibility, because the trunks of the same afferent nerves might be severed by cutting off the leg of the animal without causing it to wince or show any of the signs of pain that it would have shown had the connection of the spinal cord with the brain been undisturbed.

It is not to be supposed that the movements of the muscles are caused by the stimuli acting directly without the medium of the nerves, for if the nerve trunks are cut between their sensitive ends in the skin, and their connection with the spinal cord, no movements follow the stimulation. It is thus shown that the movement of the stimulus is actually up the afferent trunk to its junction with the spinal cord, and thence down by the efferent trunk to the muscles of the limbs. It has

been mentioned elsewhere that during the breeding season the thumb of the male frog is greatly enlarged by the formation of large papillæ upon it. The spinal cord is, at this season, also subject to much stronger excitability than at other times. The instinct of the frog at this season, is to grasp an object, naturally the female, and to hold on indefinitely, sometimes for weeks. But he will also grasp other objects, and while he is thus holding on, if he be decapitated, or the brain cut away, the grasp is not relaxed, which shows that the contraction of the muscles of these fore limbs is due to reflex action from the stimulus of the touch of the body in contact with the thumb. If the posterior part of the body be cut away, the grasp of the thumb will continue, but it will relax immediately when the part of the cord which receives the nerve trunks from the fore limbs is cut out or disconnected.

Again, if, after the brain is gone or disconnected from the spinal cord, the skin on the side of the frog be touched with acetic acid, the foot on the same side will be raised and rubbed against the place as if to rub off the acid; and still more remarkable, if that foot be held so it cannot be used, the other will, after a time, be extended across the body in an effort to do the rubbing. (*Huxley.*) To a frog in possession of his brain, the application of acetic acid to the part indicated, is painful. But when the stimulus reaches the spinal cord only, and is reflected from there to the limbs, there is every reason to conclude that sensation is not aroused. It may be doubted in this case whether the spinal cord alone was responsible for all these rather complicated muscle combinations. In all probability it was assisted by the centers in the medulla oblongata. The account is not sufficiently explicit as to the exact point at which the section of the brain was made. It is not likely that the frog possesses sensibilities different from those of the salamander, an amphibian like himself. His consciousness depends, like that of most other vertebrates, on the more anterior ganglia of the brain. The performance of reflex actions does not, however, depend upon the absence of consciousness. If, for example, the foot of a ticklish person be touched with a feather, although the person may be conscious of what is going on, the foot is withdrawn without any effort of his will, and even against it. The action is the same in this case as it would be in the unconsciousness of sleep, for the foot would be withdrawn just the same. In both cases the movement of the foot is reflex. In the first one the irritation is strong enough to arouse the consciousness as well; in the last one, it is not. Thus it appears that reflex action does not depend one way or another on consciousness, but both the action and the consciousness depend on the stimulation. In the case of our frog, his actions in withdrawing his tickled limb, and in attempting to rub off the acetic acid, are just what they would have been if he had possessed

his brains. But in the absence of brain and consciousness there is no possibility that the action could be complicated by any other stimulation than that applied to the particular nerves in question. This irritation has all its own way, therefore, with the frog, and this much of the animal is a machine which, whether in consciousness or not, is equally under the influence of the stimulus, the consciousness, if it is manifested at all, being a secondary matter, not antecedent or necessary to the effectual operation of the stimulus, nor contributing anything to it, but arising out of it. In the case of the paralytic patients it must likewise be maintained that the part disconnected from the brain and its influence, is a machine worked exclusively by the influence of the external stimuli.

Ferrier says: "It is clear, from an examination of the reactions of the brainless frog, that the movements are not mere muscular contractions of individual muscles, but muscular combinations of greater or less complexity, acting synergically for a definite end. It is obvious, therefore, that the spinal centers are themselves the co-ordinating centers of a great variety of adapted movements." When there is local disease of certain parts of the anterior horn of the spinal cord, certain synergic or co-operative combinations of muscles become paralyzed; stimulation of the different motor roots of the spinal cord for the limbs, according to the experiments of Ferrier and Prof. Yoe, on monkeys, on the other hand, give rise to the movement of their corresponding limbs in more or less complicated actions. "Thus, stimulation of the second dorsal root excites the action of the intrinsic muscles of the hand, as seen when the animal is resting on a perch; the first dorsal brings into play a great number of muscles, the general result of which may be compared to plucking a fruit and drawing it towards the trunk: the eighth cervical causes a complication of movements, which brings the tips of the fingers into the position requisite for scratching the buttocks, the *scalptor ani* action; the seventh cervical innervates the muscular actions, which, supposing the hands were the fixed point, would cause the body to raise up, as in mounting a branch or trapeze; while the sixth cervical brings the hand up to the mouth;" and stimulation of the fifth cervical causes the arm and hand to be raised upwards and backwards. Then the stimulation of various lumbar roots effects various more or less complicated movements of the legs and toes.

"The experiments of Ward, and also those of Yung, show that in the cray-fish each segment of the ganglionated cord is the center for the movements of the corresponding somite[1] That the same holds good for the segments of the cord in vertebrates, though perhaps not to the same degree of independence seen in the cray-fish and other members

[1] See Ferrier's Functions of the Brain, 78.

of the annulosa, is proved by the experimental determination of the position for other centers, for actions of a considerable degree of complexity." After cutting the spinal cord *above* the lumbar enlargement, Goltz and Freusberg found that very complicated functions are performed through this lower nerve center, even when it is thus disconnected from the brain, and the animal, therefore, in a state of unconsciousness. Nerves from this center reach the intestines, rectum, bladder and reproductive organs. The action of all these parts may be carried on in a normal manner in dogs of both sexes, when mutilated in the above manner, even to the production, by appropriate stimulation, of sexual excitement and impregnation, followed in due time by normal automatic parturition. On the other hand, the operation of all these organs is summarily stopped, if this part of the spinal cord is destroyed, even when all the rest of the nervous system and brain are intact. When the brain of the animal is in normal connection with the spinal cord, it is sometimes, but by no means always, the medium or route through which the stimulus passes from the environment to the cord. When it is disconnected, as in the case of the above experiments, the stimulus applied by the operator to the motor roots and nerves, supplies in some cases, that which the brain should furnish, and demonstrates the purely mechanical nature of the entire apparatus.

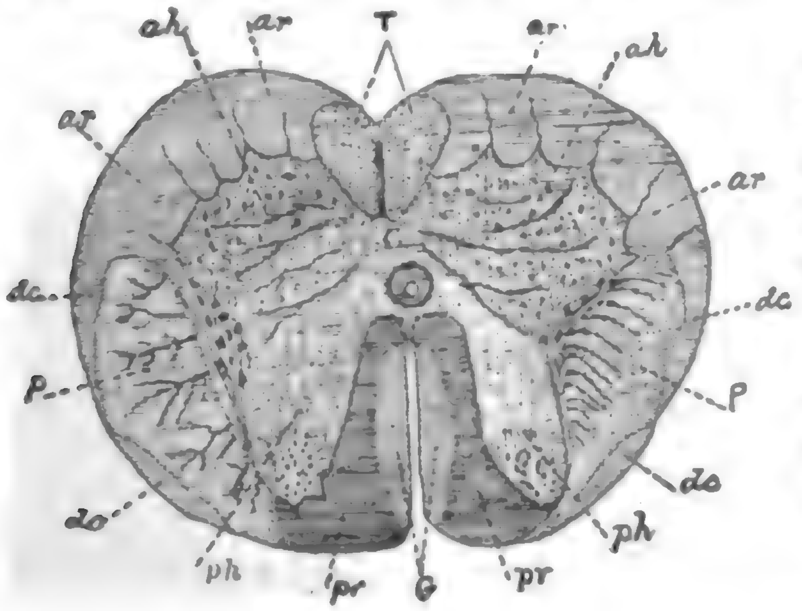


FIG. 347.

FIG. 347.—*Transverse section of spinal cord. Human embryo at five months. (From Ferrier.)*
ah.—Anterior horns of gray substance.
ph.—Posterior horns of gray substance.
ar.—Root zones of efferent (or anterior) nerves.
pr.—Root zones of posterior, or afferent nerves. (Columns of Burdach).
T.—Columns of Turck.
G.—Columns of Goll.
dc.—Tracts leading directly to the cerebellum.
p.—Pyramidal fibres of lateral columns.
c.—Commissure between the two halves of the spinal cord.

As already mentioned, the nerves which reach the spinal cord from the various parts of the body do not all have the same destination. Some, both afferent and efferent, end at the ganglia and gray vesicular matter in the spinal cord where they first reach it. Others continue up the cord and terminate in the medulla oblongata; others go on to the cerebellum; and still others go to the optic thalamus without break of connection. The figure (347) of a cross-section of the spinal cord shows the position in the cord of some of these tracts.

The general columns of gray matter in the spinal cord extend its whole length, but the gray matter is more abundant at the points where

the spinal nerves join the cord. A tract, called *Clark's column*, of vesicular or gray matter is found at the inner side of the base of the posterior horns of the spinal cord. It extends up and down the cord between the 9th dorsal and 7th cervical nerves, but the vesicles are more abundant between the 9th dorsal and 3rd lumbar. From these Clark's vesicles are traced fibres,* which run into the cerebellum without break, and which are called the direct cerebellar tracts (*dc*, fig. 347). They pass through the restiform tracts into the superior vermiform process (middle lobe) of the cerebellum. These tracts, the posterior root tracts (*pr*), and the columns of Goll (G), are all afferent, or sensory. The columns of Goll extend upward to the clavate nuclei in the medulla oblongata, opposite the calamus scriptorius. In man they begin about the middle of the dorsal region. In monkeys they commence as low down as the lumbar region. They increase in size as they ascend.

There are two pyramidal tracts, one direct, the other crossed. The *direct* one is continuous with the pyramid in the medulla oblongata on the same side. It is in the front part of the column next the median fissure. (Fig. 347, *T.*) They are also called columns of Turck. As they pass down the cord they finally decussate through the anterior commissure of the cord by the time they reach the middle of the dorsal region. The *crossed* pyramidal tract is a continuation of the opposite pyramid in the medulla oblongata. It occupies the posterior part of the lateral column of the cord. (Fig. 347, *P.*)

CHAPTER LX.

FUNCTIONS OF THE MEDULLA OBLONGATA.

The functions of the medulla oblongata acting alone without the interference of stimuli from the cerebrum, are, like those of the spinal cord, purely reflex. It, however, is connected with a different set of nerves, and consequently its specialties are different. All the cranial nerves, except the first four, viz., the olfactory, optic, motores occulorum, and the pathetic, have their roots in the medulla oblongata. The first four also have more or less direct connection with it, and so have the nerves of touch by way of the spinal cord. So that the reflex actions that may be excited through the medulla are much more varied and complicated than those excited through the spinal cord alone. The medulla is the center for the nerves controlling respiration and other vital functions, from which circumstance it happens that the brain may be removed from above it, and nearly the whole spinal cord from below, without immediately destroying life. These functions proceed automatically.

The reflex action of the eyelids in winking, when there is sudden irritation through the optic nerve and retina by an object coming close, arises from the return stimulus along the ophthalmic branch of the 5th pair. The contraction and dilation of the pupil is also automatic and reflex through the optic nerve and the 3rd pair. The periodical winking which takes place with all several times a minute, is likewise reflex, the stimulus probably being a result of the evaporation of the fluid upon the eyeball. These movements may all take place consciously, that is, when the attention is not occupied with stimuli of greater force. But ordinarily they go on without arousing sensation, and they cannot long be restrained or controlled by those other stimuli which constitute the will. It is shown in certain cases of disease of the optic nerve centers, that while the possibility of a *sensation* of light is destroyed, yet the pupil contracts through the stimulus of light upon the retina. Sneezing is another reflex action arising from stimulation of the pituitary membrane by irritating substances, the vehicle being nerves belonging to the 5th pair. Coughing, too, is reflex from the stimulation of irritating substances in the air passages; the vehicle in this case being branches of the pneumogastric pair. The act of swallowing is entirely reflex, and is caused by the stimulation of the food upon the mucous membrane of the fauces and root of the tongue. This stimulation is carried to the medulla oblongata chiefly by the glosso pharyngeal, assisted, however, by fibres of the trigeminum, or 5th pair. The return, or motor, influence is conveyed to the muscles of the pharynx chiefly by the branches of the pneumogastric (10th pair), assisted by branches from the facial, the trigeminum and the hypoglossal pairs. The movements in the pharynx may or may not be accompanied by sensation. When the food has passed through the pharynx and reached the esophagus, it is propelled along that canal by its peristaltic action, which is also purely reflex and devoid of sensation. Its action is caused by the stimulation of the food upon its mucous lining, which stimulation is carried to the ganglion in the medulla oblongata and returned to the muscular layer of the gullet, which thereupon contracts rythmically from top to bottom, driving the contents along and forcing them through the cardiac sphincter into the stomach. The nerves concerned in this action are branches of the pneumogastric.

In vomiting, the action of the esophagus is reversed, the rythmic contraction beginning at the bottom instead of the top, the contraction of the cardiac sphincter is relaxed, the stomach contracts, and its contents are expelled upward into the gullet. This action is automatic, and is brought about through the pneumogastric nerves, although not in all cases caused by direct stimulus upon the mucous coats of the organs themselves, since it is sometimes provoked through the emotions, as of

disgust in seeing, smelling or tasting something abominable. It can be produced by tickling the fauces, or by the subcutaneous injection of tartar emetic, &c., also by the dizziness arising from swinging, sailing, riding backwards, &c. All of these stimuli, as well as those directly disturbing the stomach by their offensive presence in it, appear to overflow into the pneumogastric system of nerves, and convey through it the stimulus necessary to relax the cardiac sphincter muscle and allow the regurgitation of the contents of the stomach. The simple distension of the stomach by a superabundance is enough to cause this reversal in infants and young children. In all these cases the action is directly reflex, as regards the stomach itself, while as to the gullet it is a sort of associated reflex action, the state of the stomach constituting a stimulus which is carried to the nerve center from the stomach, and back along several of the efferent branches of the pneumogastric at once, a single stimulus thus affecting a group of motor nerves and producing associated movements in several related and co-operating organs. That the actions are governed from a common center, and are not directly dependent on each other, is shown by the fact that when vomiting is caused by injection of tartar emetic into the veins, the reversed peristaltic action of the esophagus goes on even if it be separated from the stomach. (*Carpenter.*)

The act of sucking, by which all mammal infants, including man, get their early supplies of food, is purely reflex. An infant will suck anything put into its mouth. And so will a calf or any other mammal baby. The article in contact with the lips furnishes the stimulation by touch, and the transmission of the stimulus to the medulla oblongata, and from it to the various muscles concerned in the act of suction and swallowing, is shared by several nerve trunks, the trigeminum, facial, glosso pharyngeal, pneumogastric and hypoglossal, all perhaps having something to do with it in one direction or the other. All this machinery is set in motion in an unconscious infant. The same thing takes place in those monstrosities which are sometimes produced, destitute of cerebrum, which nevertheless breathe, and suck and swallow their food. So, too, puppies from which the brain had been cut away, would suck whatever was placed in the mouth. In the case of infant mammals with all their faculties, it is not long before other stimuli come into play to assist the one of touch upon the lips. As Carpenter points out, the infant goes in search of its food, guided by the sense of smell, perhaps, and touch stimuli other than that of the lips. The actions are still, however, reflex, although in the course of time they are accompanied by sensation.

Beside the movements that are reflex from the medulla oblongata alone, there is a long list in which the medulla is concerned in connec-

tion with the spinal cord in actions purely reflex, and often quite complicated, and executed as well in the absence of sensation as when it is aroused. If from a frog the cerebrum be removed, with care not to injure the optic lobes, or any of the nervous system back of them, the frog may be kept alive and in full bodily vigor for months or even years. It will not of its own accord move, but sits stationary. It does not seem to see or hear. It will not feed itself, but will swallow food placed in its mouth. "On irritation it jumps or walks; if thrown into the water it swims. If it be put on the hand it sits there crouched perfectly quiet, and would sit there forever. If the hand be inclined very gently and slowly, so that the frog would naturally tend to slip off, the creature's fore paws are shifted onto the edge of the hand until he can just prevent himself from falling. If the turning of the hand be slowly continued, he mounts up with great care and deliberation, putting first one leg forward and then another, until he balances himself with perfect precision upon the edge, and if the turning of the hand is continued, over he goes, through the needful set of muscular operations, until he comes to be seated in security upon the back of the hand. The doing of all this requires a delicacy of co-ordination, and a precision of adjustment of the muscular apparatus of the body, which are only comparable to those of a rope dancer." Notwithstanding the animal appears blind, if he be put upon a table with a book at a little distance, and between it and the light, and he then be irritated by a touch on the hind part of the body, he will jump forward, avoiding the book by passing to the right or left of it.[1] It is evident that the frog sees without having the perception of sight. That is, its sight stimulation effected through the retina, is transmitted through the sensory ganglia, and coordinated with the stimuli of touch, and has its modifying influence on the motor action developed, without arousing any sensation, just as the touch stimuli alone would cause it to jump blindly and without sensation of the touch. If the brain of the frog be cut away so as to include the optic lobes in the abscinded part, it is still able to sit in its ordinary position, and of itself it would not move. But if touched or stimulated in some way it will jump or walk, and if thrown into the water it will swim. The cerebellum with the medulla oblongata and the spinal cord, here comprise a complete governing apparatus for the motor machinery of the frog.

Goltz obtained examples of quasi purposive movements, and also expressions of satisfaction in a decapitated frog, by stimuli applied to it. The movements of the limbs to rub off acid applied to the skin, have been mentioned. The quack or croak, expressive of satisfaction, he elicited by stroking the creature gently on the back, and the movement

[1] See Huxley on Automatism. The first experiment of this kind was made by Goltz, and published in 1869.

of the male to embrace the female, as in reproduction, was produced by gentle pressure and rubbing, at the proper season, of its breast and the inside of its arms.[1] We have in the acts of the headless frog, the same actions which would have followed the same stimuli if his head had been on. We are at liberty to conclude that such consciousness as the frog possesses is not an essential link in some of the most important of his actions.

"The medulla oblongata is a center of facial and of some other forms of what is usually regarded as emotional expression. Vulpian has shown that if a young rat be deprived of all the encephalic centers above the medulla oblongata, pinching of the toes will cause not merely movement of the limbs, but also a cry as of pain. If the medulla be now destroyed, pinching the toes will cause reflex movements of the limbs as before, but no cry will be elicited. The cry as of pain is, however, no real sign of pain, but only a reflex action of the laryngeal and expiratory muscles." (*Ferrier.*)

The foregoing would indicate that the medulla oblongata is the co-ordinating center for the production of articulation. A disease known as *bulbar paralysis* begins by paralyzing the tongue, then proceeding to the lips, palate, pharynx and larynx, impairing and finally destroying the functions of articulation, swallowing, and even the production of sound. It is found to depend upon degeneration about the roots of the 7th, 9th, 10th and 12th pairs of nerves, in the medulla oblongata.

It scarcely needs to be pointed out that the nature of reflex actions depends on the habit of the organs operated upon. Most individuals affect some gesture, movement or mannerism peculiar to themselves. In unguarded, that is, unconscious, moments, such movements are apt to exhibit themselves, and we have no hesitation in attributing them to habit. The accumulation of nervous energy, which is constantly going on, must needs have occasional escape, and the path it takes is the one leading in the direction of the least resistance. This, in the absence of purposive motives, is apt to be in the direction of a useless mannerism, sometimes a hurtful one. The oftener such movement takes place, the greater the facility, and the more likely the movement is to take the same track. It often happens that the excitement generated in the performance of some action, either of brain or muscle, is greater than necessary for such performance, or from the want of concentrativeness cannot all be directed toward such performance. In such cases, the surplus energy goes into the mannerism, trick, or useless habit. It often happens that the trick so constantly accompanies the performance of a certain mode of action that it gradually assumes the relation of a necessary companionship, so that the legitimate action cannot be easily per-

[1] Maudsley's Body and Will, 107.

formed if the companion trick be forcibly restrained. I have somewhere seen an account of the keeper of a Scotch castle who was blind, and who had a habit of carrying about a key when he conducted people over the place. When this key was abstracted from him he became so disconcerted as to lose his way. Fumbling the key was so associated with his movements about the structure, that the latter could not take place without the former. The numerous superfluous taps which every blacksmith gives his anvil, afford another illustration of the reflex course of undirected energy along the line of habit.

But we are also bound to observe that the very same law governs purposive action as well as reflex action. The energy will operate in the line of the least resistance, which is still generally the line of habit. The great majority of all our actions are simply imitations of similar ones gone before. We find ourselves every morning under an impulse to do the same things we have done every other morning for years back. As the day wears on we are assailed by a recurrence of the same succession of impulses. Our actions are in detail practically the same day after day, and although we suppose them to be performed in consciousness, we shall find, if we attempt to recall them in memory, that by far the greater part of them are not. Our steps in walking, the gestures and movements of our hands and head as they are influenced by the senses of sight and hearing, are, in ninety-nine cases out of a hundred, unconsciously reflex. The habits of ordinary motion are so well established as to excite consciousness in but a slight degree, and generally not at all.

The relationships of the different kinds of motion to each other are, in some cases, inconstant and various, and consequently are not habitual. It is therefore these relationships which most frequently arouse consciousness. We may know why we walk, and the points of departure and destination, although unable to recount the steps taken, or the commonplace objects encountered on the way. The motive of which we are conscious, and which originates in the higher brain centers, has an effect upon the ganglia of the medulla oblongata in the same way that those stimuli have which come from the environment direct, or from the visceral organs and muscles of the body. Whatever the source of the stimulations which reach the nerve centers of the medulla, these centers inaugurate actions in the parts which they control, in manner and detail entirely machine-like, and independent of the will, so that the purposive actions which require the co-operation of the centers in the medulla oblongata, are purposive only as to the *end* to be attained, and not the means. The purpose as a stimulus, takes rank alongside of the other stimuli which are competent to touch off the nerve centers; such as a feather in the throat, or a microbe in the lungs.

In the medulla oblongata, then, are the centers for the co-ordination of the movements concerned in respiration, and in the modifications and interruptions of it, in coughing, vomiting, sneezing, singing, talking, &c. The hypoglossal, glosso-pharyngeal, facial, and fifth nerves, which are concerned in the co-ordination necessary for swallowing, either as afferent or efferent, all originate in the gray nuclei in the medulla. The muscular movements necessary for articulate speech, are co-ordinated in the medulla oblongata, the nerves concerned being the hypoglossal, the vagus, accessory, facial, and glosso-pharyngeal. Cries, exclamations, and other forms of vocal expression, are co-ordinated in the medulla.

The breathing apparatus has its nucleus of co-ordination in the nuclei of the vagus nerves, near the beak of the calamus scriptorius. The stimulations which are co-ordinated are those from the lungs themselves, through the vagus, and also those from the general nervous system, especially of the head and face. The state of the blood has an effect on respiration. The end, or object, of respiration, is the oxidation of the blood, so that if the blood be hyper-oygenated, the movements of respiration automatically stop, and if any cause prevents oxidation of the blood, the automatic efforts to breathe will be greatly stimulated

All these automatic and reflex regulations of the blood pressure, are co-ordinated through the medulla oblongata, and they may go on all right even when all the brain centers above the medulla are abolished. Respiration, heart-beating, and blood circulation, swallowing food put into the mouth, digesting it, performing various reflex and even highly complicated movements of limbs and jaws and throat, involving the utterance of cries, &c., are accomplished through the action of the nerve centers of the medulla oblongata when the cerebral hemispheres and the rest of the ganglia are gone. The vaso-motor region, or the centers influencing the tone of the blood vessels, blood pressure, &c., are in the anterior portion of the lateral tracts of the medulla.

The interference of the centers in the medulla with the beating of the heart, was mentioned in chapter 53. The immediate effect of this interference from some of the centers, is acceleration of heart movement, and the excitement of these centers, which thus overflows to the heart, may be aroused by the active exercise of the muscles. When muscular exertion takes place, nervous energy is evolved, which passes up the afferent muscle nerves to the medulla, and thence down the acceleration nerves by way of the first dorsal sympathetic ganglia to the heart, which thus receives a double stimulation; viz., first, that habitually made in its own tissues by the consumption of the blood furnished by its coronary arteries; second, that which is thus casually furnished by the blood used up in a distant muscle. The effect of the acceleration is to furnish more blood to the part at work.

Another effect on the heart is the inhibitory or retardatory action which comes through the vagus nerve. The excitement in the vagus nucleus, which thus overflows to the heart, may be induced by powerful irritation of the sensory (afferent) nerves generally, as when a person suddenly tumbles into cold water; or of the sensory branches of the fifth pair in the nostrils, or of the sensory nerves in the larynx, and particularly of the intestinal sensory nerves. (See chap. 53.) There are also "mental states," that is, conditions of the cerebrum which stimulate the retardatory centers.

The medulla is also a co-ordinating center for the reflex associated movements of the limbs, and the muscles of different parts which act together and in harmony for a definite end, when the influence of the cerebrum is cut off, and the subject, therefore, in a state of insensibility, and also those movements, such as swallowing, which are constantly being performed by associated action, without the supervision of the will, and often in opposition to it. The muscles of the face are also subject to regulation and control through the medulla oblongata. It is the various degrees of contraction of the different muscles of the face that give what is called *expression*. An action of a certain sort, in the stomach, for example, sends a current to the medulla, from which it overflows to the muscles numbered 12 and 21 (and others) in fig. 66, and gives what we have learned by observation to be expression of pain. Another, irritation on the bottom of the foot, as with a feather, sends up a current which becomes reflected to muscles 9, 22, 23, &c., giving an expression of laughing. Different conditions in various parts of the body, constantly send up their stimuli to the medulla, from which they are reflected to muscles not only in the face but in all parts of the body, causing contractions of the muscles in first one part and then another, which give rise to the innumerable unconscious movements of the limbs, and the postures, gestures, tricks, mannerisms, smirks and grimaces, that we are performing every moment of our waking hours. The power which runs all this machinery is not generated in the nerve centers, but only balanced and co-ordinated there.

CHAPTER LXI.

FUNCTIONS OF THE CEREBELLUM.

The large amount of vesicular brain matter in the cerebellum, marks this organ as a great laboratory of nervous stimulation, condensing many simultaneous stimuli, so that a single resultant motor action may follow, and dispersing other single stimuli into many channels, by which as many different motor actions are set up or modified. The cerebellum

has been sufficiently described. Its connections with the medulla oblongata and the spinal cord are especially intimate, and its functions must therefore be considered as having been developed in relation to the functions of those parts. It has no direct connection with the cerebrum, and the natural inference would be that although it may be subject to a special influence from that organ, and no doubt it is, nevertheless it is a complete machine of itself, operated by a set of stimulations from the sense organs through the medulla oblongata, which are competent to set up action in it entirely independent of the cerebrum.

Throughout the vertebrate sub-kingdom we find the development of the cerebellum to correspond with the degree and energy of muscular co-ordination possessed by the animal. Among the fishes, reptiles and birds, this organ is relatively large in those having the most diversified and complicated modes of muscular action, as shown in chap. 58. The same is shown in the mammals, the cerebellum increasing in relation to the spinal cord, in the proportion in which the muscular co-ordinations and activities increase. The cerebellum of birds is larger than that of the lower mammals. But in those mammals in which the activities involve complicated and co-ordinated movements of the several muscles, the cerebellum is of corresponding size. The differentiation of the limbs from mere organs of terrestrial or aquatic locomotion, to organs adapted to digging, climbing, flying or grasping, involve an increase in the condensing and distributing power of the cerebellum. All such differentiations of limbs involve the fore limbs to a much greater degree than the hind ones. The latter are generally reserved (in the land animals) for terrestrial locomotion chiefly. But as the fore limbs are gradually developed into greater dexterity, they resign to the hind limbs the task of locomotion, which involves the maintenance of an upright position on those limbs, and calls into use a greater variety of muscles, and requires a more delicate balancing and constant tension of those muscles. Thus compare the turkey with the lizzard, figs. 298, 296. The cerebellum of the latter is hardly as large as the optic lobes, while that of the former is not only very much larger, but is greatly increased in effectiveness by its numerous transverse convolutions. The chief superiority of the brain of the bird over that of the reptile, is in the cerebellum. The cerebellum of the bear is likewise superior relatively to that of the dog, and the former is correspondingly much more handy with his fore paws in climbing and grasping, and much better able to use his hind legs in standing and walking in an upright position.

In the man-like apes, there is a great advance in the cerebellum over that of the inferior mammals. And in their activity, the variety of their movements, and their ability to sit or stand on their lower extremities while using their fore limbs as hands and arms, they are far su-

perior to all other mammals except man. Man is excelled by many other animals in one form or another of muscular activity; a hound can outrun him, a squirrel can outclimb him, a kangaroo can outjump him, a fish can outswim him, and he cannot at all compete with a bird in flying. In the use of his fore limbs, however, he is far in advance of all of them, and although he cannot fly, the versatility of his movements is much greater than that required for flight. His cerebellar development is greatly in excess of that of any other animal. In the human race, the cerebellum develops with the greatest rapidity during early childhood, the period in which the greatest number and variety of muscular combinations are being practiced; the period in which our race most resembles the ape in all these and other particulars.

In all those animals which begin to use their muscular powers as soon as born, the cerebellum is well developed at birth. A chick only a few hours old can peck at a June-bug with very accurate aim, and, as shown in fig. 301, its cerebellum is then well developed.

Experiments on individual animals bear out the theory that co-ordinations of muscular stimuli take place in the cerebellum. It is possible, in many cases, to remove either the cerebellum or the cerebrum without immediate destruction of life. When the cerebrum alone is taken away, the power of muscular movement is not destroyed, as the experiments with the frogs, mentioned in chap. 60, prove. The same experiments have been made upon all classes of vertebrates with practically the same result. A bird deprived of the cerebrum loses its sensibility, or the most of it, and appears stupid, but does not lose its power of muscular co-ordination. It will not take food, but if food be placed in its mouth it will swallow it, and digestion and excretion will go on as in the unmutilated animal. It will sit or stand for a long time in one position, will scratch itself and prune its feathers, if thrown into the air it will fly, if pushed it will walk. It appears, moreover, to be influenced through the optic lobes, for if placed in a room partly lighted, it will move to the best illuminated part of it, and will pass to one side of obstacles lying in its way. A case is mentioned in which a pigeon, deprived of its cerebrum, was affected by the light sufficiently to cause the contraction of the pupils when exposed to it suddenly, after confinement of the bird for a time in a dark place. And when a lighted candle was moved before the eyes of the bird, the head followed the light by a corresponding movement. A vertiginous movement may be induced in pigeons by simply blinding one eye. (*Carpenter.*)

Dr. Ferrier's experiments on the cerebellum prove that it has a control (though certainly not an exclusive one) of the ganglionic centers of the "motor nerves of the eye, every kind of movement of the eyeballs, even rotation on their antero-posterior axes, being capable of ex-

citation by stimulating some particular portion of the organ. The localization of the centers of combined movements of the two eyeballs, in particular lobules of the cerebellum in the rabbit, was extremely curious. Thus, when the electrodes were applied to the median lobe at its forward end, the right eye moved outwards and the left inwards, in a horizontal plane. When the center and posterior parts of the middle lobe were irritated, the right eye moved inwards and the left outwards, on the same horizontal plane. Thus it appears that the middle lobe regulates those horizontal movements of the eyes which are harmonious but not symmetrical, and that the upper part of the median lobe and its middle and lower parts, are in functional antagonism. When the electrodes were applied to the forward part of the *left* lateral lobe, the right eye moved downwards and outwards, the left eye upwards and inwards; and when the corresponding point of the right lateral lobe was stimulated, the right eye moved upwards and inwards, and the left eye downwards and outwards, while the conjoint irritation of both lateral points neutralizes both effects. When the middle division of the left lateral lobe was irritated, a downward movement of the right eye, and an upward movement of the left eye, were combined with a rotation of each globe on its antero-posterior axis, the left in the direction of the hands of a clock, the right in the contrary direction. But when the irritation was applied to the posterior or lowest division of the left lateral lobe, the two eyes rotated on their antero-posterior axes in the same direction, and contrary to the hands of the clock, so that their vertical meridians retained their parallelism. This last action is what takes place automatically when we fix our gaze at any object, and incline our head to the right side, the rotation of the eyeballs in the opposite direction serving to keep the image of the object on the same spot of the retina, just as do the automatic movements of the eyeballs in the vertical or horizontal plane, when the head is moved upwards or downwards, or from side to side." (*Carpenter.*)

These experiments make it evident that one very important function of the cerebellum is to regulate the movements of the eyes, and to harmonize these movements with the other general muscular motions of the body. Dizziness, resulting from swiftly turning, or from crossing running water, unsteadiness of gait when blindfolded, or in the dark, &c., are due to a failure of this co-ordinization, or harmonizing. The direction of the vision is changed too rapidly to allow of one adjustment to be completed before another becomes necessary, or the absence of the directing vision leaves the muscular movements without any other guidance than they can get from the muscular and auditory senses.

It is not known with certainty by what nerve connections the eyes and the cerebellum are united, but it is thought it is from the pulvinar of

the left optic thalamus crossing over to the right superior peduncle of the cerebellum, and vice versa, from the right thalamus to the left peduncle. On account of the decussation of the optic nerves, this second decussation puts each eye into relationship chiefly with the part of the cerebellum on its own side. This accounts for the fact that electrical irritation of the cerebellum contracts the pupil of the eye on the same side. Lesions of any part of the tract connecting the eyes with the cerebellum, as the corpora quadrigemina, optic thalamus, superior peduncles, and their intermediate nervous connections, have the effect to disturb the functions of equilibrium.

It has been found that "section of the horizontal semicircular canal in the ear of pigeons, on both sides, induces a rapid, jerking, horizontal movement of the head from side to side, and a tendency to turn to one side, which manifests itself whenever the animal attempts to walk forwards." If a vertical canal on each side be cut, the movement is vertical and violent. These movements continue for months. Similar results occur from like operations upon the ears of rabbits. These phenomena indicate that the sense of hearing enters into the combination of stimuli concerned in certain muscular co-ordinations, and the elimination of a subdivision of this stimulus deranges the habitual normal balance, and renders the animal dizzy, with an effect similar to that induced by partial blindfolding.

The anterior division of the auditory nerve, which is connected with the ampullæ and the semicircular canals, sends some of its fibres directly to the cerebrum, while others appear to ascend to the cerebellum through the restiform tract. Lesions, or diseases of the cerebellum, do not, however, cause deafness either in man or the other mammals. But the anatomical connection between the semicircular canals and the cerebellum, is no doubt the reason why injury to the canals has the same effect as injury to the lobes of the cerebellum. Section of the superior vertical canals causes loss of balance forwards, and so does lesion of the anterior part of the middle lobe of the cerebellum. Section of the posterior vertical canals causes a tendency to fall backwards, and so does injury to the posterior part of the median lobe. Section of the horizontal canals causes a lateral rotary motion, and so does injury to the lateral lobes of the cerebellum.

It is clear from these facts that a part of the afferent stimuli, upon which the functions of the cerebellum are founded, come from the ears, and are auditory stimulations. Whether it be found that the functions of the cerebellum include general muscular co-ordinations, or only such as relate to the preservation of a normal equilibrium, we should consider it antecedently probable that there must be some connection between it and the eyes. The dizziness caused by whirling around, or by

looking steadily at a swiftly moving body of water, prove the influence of optic stimulations in the balancing functions. The dependence is not mutual, however, for lesions of the cerebellum have no effect upon the eyesight, never produce blindness.

The sense of feeling, or tactile sense, including heat, pressure and the muscular sense, is, of course, a necessary factor in the function of equilibration and co-ordination. Tactile impressions reach the cerebellum by way of the olivary bodies and restiform tracts of the medulla oblongata. Injury to the restiform tracts disturb equilibrium in the same way in which it is done by injury to the semicircular canals, with rolling and tumbling motion of the body, and turning of the eyes; nevertheless the cerebellum has nothing to do with conscious sensation of touch, and injury to it does not impair tactile sensation. Neither does section of the restiform tracts, nor of the connected posterior columns; the restiform bodies being related with the posterior columns through the olivary bodies, the restiform of one side being connected mainly with the posterior column of the opposite side.

The fibres of the pyramidal tracts of the medulla oblongata which cross each other in the pons varolii, are those which relate to the cerebral hemispheres only. Those which form connections with the cerebellum are not crossed, so that a stimulation which involves both cerebrum and cerebellum will affect the right lobe of the cerebellum, and the left hemisphere of the cerebrum, or vice versa. See fig. 375, which shows an example of the decay of the cerebellum, following and consequent upon loss of function in the cerebrum, and also shows the normal subordination or correspondence of the functions (or some of them) of the former to the latter. Ferrier remarks that the "functions of the cerebellum are outside of the sphere of mind proper, as expressed in sensation, emotion, volition and intellect."

If the peduncles of the cerebellum be divided, the effect is a rolling motion of the animal sidewise and very rapid. If the peduncle be divided from behind, that is, the portion derived from the restiform column called the posterior peduncle, the rolling is towards the side on which the injury is made. (See figs. 267, 271, 273.) But if the section be made in front, in the anterior peduncle, the turning is from that side towards the other. This difference is supposed to be caused by the fact that the fibres of the anterior peduncle connect largely with the decussating fibres of the anterior pyramids of the medulla oblongata, so that the anterior peduncle of one side, and the posterior peduncle of the other, connect with the same tract of motor nerves. The severance of the posterior peduncle, or part of it, disconnects the cerebellum from the afferent stimuli, through the restiform columns, while the severance of the anterior peduncles cuts off an outgoing stimulus to certain

muscles, leaving certain others free to effect a twisting of the spinal column, the balancing influence of the cerebellum being suspended. The injury to the cerebellum is not usually accompanied by a loss of sensibility. A bird deprived of its cerebellum can perform any single reflex muscular movement, such as to kick with its legs, or flutter its wings, but it cannot stand, balance itself, or walk, since these acts are compound, and require a combination of muscular movements. It does not lose the sense of sight, or other senses, or become stupid or affected with convulsions; effects which follow the loss or injury of the cerebrum. Inflammation of the membranes covering the cerebellum does not produce delirium, and it may be nearly destroyed by softening without entailing a loss of intellect. But almost all sorts of injuries to the cerebellum entail a loss of muscular control, unsteadiness of gait, or eccentric muscular movements, none of which effects follow lesions of the cerebrum.

A girl died of phthisis, at Lancaster, Eng., in 1884, at the age of 15, whose brain was found to be in the following condition: whole weight 42 oz., cerebrum well developed, corpora quadrigemina of normal size and appearance, cerebral peduncles all right. But the olivary bodies of the medulla oblongata, the pons varolii and the left lobe and vermiform process of the cerebellum, were nearly obliterated, while the right lobe, which constituted its main portion, was only a half square inch in size, and a quarter of an inch thick at the base. This lobe, however, had the normal laminated appearance and structure. This person had been somewhat weak in intellect, but was not deficient in "her sensory faculties, general or special, and the only peculiarity observable in her motor powers was a general muscular weakness, and tremor of the hands when she was using them (but this was attributed to the debility associated with her phthisical condition). But she could walk well and steadily, though she was never known to run." (*Ferrier.*)

A girl named Alexandrine Labrosse (reported by Combrette) "lived to the age of eleven years, and it was found after death that the cerebellum was entirely atrophied, its place being occupied by a cyst containing serum. Physically, she was well developed for her age, but she was five years of age before she was able to stand, and at the age of seven she was very insecure on her legs, and often fell. Her intelligence was defective, and her articulation indistinct, but all her sensory faculties were normal."

In cases of congenital deficiency of the cerebellum, like the above, the centers of muscular movement in the *cerebrum*, which, as we shall see, exist independently in that organ, become the chief substitute for the cerebellum. Such power of muscular combination as was shown in the foregoing cases, was due to a superior education of the cerebral cen-

ters, through the force of a necessary habit of work extending over a long time.

It has been supposed by some that the cerebellum is the seat of the sexual instinct. If so, it ought to be well developed in proportion to the intensity of the instinct. But this is not the case in fishes, for some, having the strongest instinct in this direction, have the smallest cerebellum, as, for example, the lamprey, whose cerebellum is a mere transverse band of medullary matter, is nevertheless endowed with a very intense sexuality. The same is true of other fishes. The rapid development of the cerebellum at a very early period of life, when such development can surely have nothing to do with the maturing of sexual powers, and which anticipates by a long period the maturing of the sexual organs, is a strong fact against the theory.

The brain is subject to the same law of development by use, and loss or atrophy by disuse, that governs all other organic tissues. According to this law, if the theory in question be true, we ought to find a reduction of the cerebellum in those animals in which the sexual function is destroyed artificially. A series of observations on the brains of horses, show that early emasculation does not tend to diminish the development of the cerebellum.

The following table embodies the results of observations on the brains of 10 stallions from 9 to 17 years old, 12 mares from 7 to 16 years old, 21 geldings from 7 to 17 years of age. (*Carpenter's Physiology.*)

	Wt. of cerebellum in grains			Wt. of cerebrum in grains.			Proportion of cerebrum, cerebellum being 1		
	Average	Highest	Lowest	Average	Highest	Lowest	Average	Highest	Lowest
Stallions	61	65	56	433	485	350	7.07	7.46	6.25
Mares	61	66	58	402	432	336	6.59	7.00	5.09
Geldings	70	76	64	419	566	346	5.97	7.44	5.16

From this table it appears that the cerebellum of the gelding averages nearly $\frac{1}{7}$ higher in absolute weight than that of the stallion or mare, and that its proportion to its own cerebrum is likewise greater by about $\frac{1}{7}$. The absolute average weight of the cerebrum is considerably less in the gelding than in the stallion; so that we might be led to suspect that the cerebrum has more to do with the sexual functions than the cerebellum. The additional size of the cerebellum attained by the gelding, is attributed to the fact that animals of this class are taught a greater command of their muscular powers, and are subject to a greater discipline and activity, bringing out a greater versatility in the exercise of them.

Some very conclusive experiments in this direction were performed on dogs, by Luciani. He destroyed the cerebellum of a female dog in two operations, eleven months apart, and between these two operations the sigmoid gyri of both hemispheres of the cerebrum were likewise destroyed.[1] Notwithstanding this mutilation the sexual instincts were not abated, and four months after the complete extirpation of the cerebellum, she became pregnant, and parturition and the subsequent maternal offices and solicitude for the young, were performed and exercised in the usual and normal manner. A post mortem examination showed her destitute of a cerebellum, except a small fragment of the right lobe, and the sigmoid gyri were missing in both hemispheres. "This animal was never able to stand or to walk, and could only move from place to place by butting forward, and proceeding by the force of her falls. The head also was subject to continual oscillations when she tried to mouth anything. Though unable to stand up or to walk, she was able to swim, with, however, some tendency to inclination to one side." This dog was not injured except in regard to its ability to stand and move about. Another bitch, from which Luciani removed nearly the whole of the cerebellum, but not any part of the hemispheres, lived eight months after the operation. She became unsteady and stumbling in her gait, although she could swim as well as ever. She could not "land," however. The swimming, in this case, was probably due to the reflex stimulation from the touch and pressure of the water by way of the medulla oblongata.

"The cerebellum would therefore seem to be a complex arrangement of individually differentiated centers, which, in associated action, regulate the various muscular adjustments necessary to maintain equilibrium and steadiness of the body, each tendency to the displacement of the equilibrium round a horizontal, vertical or intermediate axis, acting as a stimulus to the special center, which calls into play the antagonistic or compensatory action." (*Ferrier.*) It is like a series of braces holding the body in position. *The anterior part* of the median lobe holds the body from falling *forward.* The posterior part of the median lobe holds it from tumbling *backward.* The lateral lobes contain centers for various "complex adjustments against lateral combined with diagonal and rotary displacements to the opposite side." Some of these apparently preventing tipping, and others preventing rolling to the opposite side.

Finally, the facts seem to warrant the conclusion that the cerebellum is necessary to a proper combination of stimuli in the regulation of certain kinds of muscular movements and adjustments. We have already seen that reflex muscular movements of themselves and uncombined, can be effected through the medulla oblongata, or even the spinal cord

[1] See 1, 4, 5, fig. 359.

alone. But without the cerebellum they are largely, if not entirely, unbalanced, and unmodified by each other. The stimuli which are thus balanced in the cerebellum, include, beside those of touch and heat, those of sight and hearing, and no doubt also those of smell and taste, in short, all the sense stimuli, for all are concerned and employed in the modification of muscular movement.

The cerebellum is the third complete organic machine for the conversion of afferent nervous stimulations into motor and muscular action, the spinal cord and the medulla oblongata being, respectively, numbers one and two. It is far more complicated in its operations because these operations result from the combination of a greater number of stimuli.

The tactile sense, including that of heat and pressure, and the muscular sense, are the only ones which impress themselves on the spinal cord through the nerves of "general sensibility." The medulla oblongata is subject to the impressions of the stimuli from a greater number of sources, and its resulting reactions are of a correspondingly more varied and complicated character.

The cerebellum is greatly in advance of the medulla oblongata in the *number* of stimuli by which it is competent to be impressed, and perhaps in the *kind* of stimuli, too. The medulla contains the detached nuclei of various encephalic nerves, nuclei which form more or less complete centers for the conversion of the afferent stimuli of the nerves into the corresponding motor stimuli of the same, but there is not the same combination of nuclei and co-ordination of various kinds of stimuli that occur in the cerebellum. Each system is independent of the one below it, and, if not interfered with by the one above it, is competent to act alone. It is probable, if not certain, that both the motor and sensory tracts of each is independent of those of the other.

The cerebellum appears to be, in some respects, a cross or intermediate organ between the medulla oblongata and the cerebrum, possessing internal nuclei like the former, and a cortex of gray matter like the latter. It is like the cerebrum in the fact that it cannot be stimulated to normal action by mechanical or chemical irritations, but does respond normally to the stimulus of the galvanic induction current.

CHAPTER LXII.

FUNCTIONS OF THE BASAL GANGLIA.

The Basal Ganglia consist of several ganglia of brain substance lying under and within the shell of the cerebral hemispheres. They serve two functions, sensory and motor. The sensory ganglia are the corpora quadrigemina, optic thalamus, and probably the pineal gland, or conarium. The motor ganglia are the corpora striata.

The tuber cinereum and the pituitary gland, or hypophysis, lying under the third ventricle, are small bodies of uncertain function.

The optic thalami, corpora quadrigemina and corpora striata are paired or doubled, the pineal gland, tuber cinereum and pituitary gland are single, and median in position.

Corpora Quadrigemina. Among the invertebrates, the part of the brain answering to the corpora quadrigemina, or optic lobes, is relatively more highly developed than in the vertebrates, and bears a direct proportion to the size of the eyes. Among the lower vertebrates these ganglions are relatively larger than in the higher; but amongst the mammals the high development of the other organs of sense and the cerebrum, causing a corresponding development of their brain ganglia, renders the optic organs of less relative importance. In birds, the optic lobes are much larger, in proportion to the cerebrum, than in man and the higher mammals, and correspondingly the sight stimuli enter more largely into their activities. In fishes, birds and reptiles, the optic lobes consist of two lobes or tubercles, one on each side. They are called the bigemina; in the mammals there are four, two on each side, hence the name "quadrigemina."

In all animals these ganglia, or tubercles, are the organs of sight, directly sensitive to the light stimuli from the retina. Any injury to them is a damage to the faculty of seeing, and to those qualities of mental action which depend upon light. Partial loss of the corpora quadrigemina on one side, produces partial loss of power and temporary blindness on the opposite side of the body, without, however, necessarily destroying the mobility of the pupil. But if these ganglia be totally destroyed on one side, it will cause total and permanent blindness and immobility of the pupil, with temporary muscular weakness, on the opposite side. Sometimes, when injuries are artificially produced upon animals under experiment, the destruction of the tubercles of one side produces a tendency to turn about as if the animal were giddy. Irritation of one tubercle produces contraction of both pupils. Blindness is, in many cases, caused by disease in one or both tubercles, and sometimes by disease in the adjoining parts of the crura cerebri. If the corpora quadrigemina on one side be pricked with a pin, it causes convulsions of the eye of the opposite side. The cause of the turnings and rollings is to be ascribed to convulsive contractions in some of the muscles on one side of the body. These spasmodic contractions always accompany the turnings, and their chief cause is irritation of some part of the governing brain center, which irritation may follow the slightest puncture. Rolling is merely a more intense result of the contractions that produce turning.

The stimulation of the corpora quadrigemina (optic lobes) of rabbits

causes various motions, according to the part operated upon. When the posterior pair (testes) were stimulated the result was noises of various kinds. When the stimulation was applied to the anterior pair (nates), the muscles of the back were violently contracted, causing a backward somersault, the jaws were clenched, and the pupils dilated.

These results call to mind those which follow stimulations of the cerebellum, and tend to confirm the conclusions reached; viz., that muscular co-ordinations, and the maintenance of equilibrium, are involved in the integrity of the organs of sight. It is true that if the optic ganglions are entirely destroyed, it is possible that equilibration may be recovered through the functions of the muscular, tactile and auditory senses, but those co-ordinations can of course no longer be effected which depend upon sight stimuli for their data. It does not appear to follow that the corpora quadrigemina are of themselves a complete organ for the conversion of its sensory into motor stimulations, (although such appears to have been the opinion of some physiologists). But these tubercles in connection with the corpora striata and optic thalami, or with corpora striata alone, do certainly form such a complete machine, the corpora striata being composed, as will be shown, of motor ganglions exclusively, and depending entirely on the corpora quadrigemina and optic thalami for afferent stimulations to make over into motor ones.

The optic lobes are probably something more than the mere organs of sight sensations. In them, the single and simple sight sensations are consolidated and condensed before they are forwarded to the organs of memory in the cerebrum. The eye is like a photographic instrument. When it is focused upon an object, every detail of that object reflects its light as a stimulus upon a cell of the optic lobes. If we look at a brick house, or a tree, we must see all the bricks and all the leaves that go to make up the general impression of a house and a tree, although we cannot recall any particular brick or leaf. All of these details are for a moment impressed upon the cells of the optic lobes, but are there probably so far consolidated that when the stimulations are darted forward toward the optic thalamus and the cerebrum, they are generalized into the single stimuli of house and tree. The same is true, no matter how small the object under consideration. Thus, if we look at a leaf, we undoubtedly see all its details of veins and veinlets, serrations, wrinkles, and various shades of coloring. But all these details may become so far suppressed, or merged into the general image of the leaf, that they cannot be recalled in the memory cells of the cerebrum, the general image alone being registered there. Such condensations as these, I take it, are accomplished in the corpora quadrigemina.

Optic Thalamus. This name is inappropriate, because the organ so

designated is not related to the optic sense exclusively, and is not an optic organ in any such sense as are the corpora quadrigemina. The optic thalami of birds or mammals may be destroyed without destroying sight or the activity of the pupil, neither does irritation of either of them produce contraction of the pupil. The optic thalamus is more or

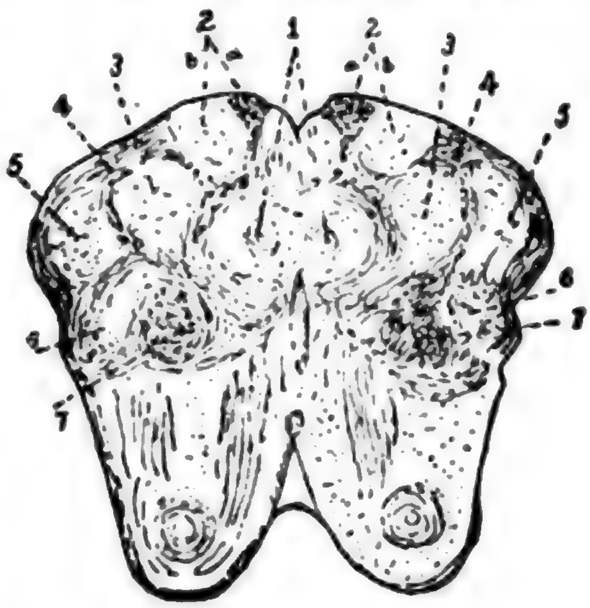


FIG. 348.—*Horizontal section of the Optic Thalami of the Rabbit, just above the level of the internal capsule.*
1.—Median nucleus.
2*a*.—Anterior cell group of Tuberculum Anterius.
2*b*.—Posterior cell group of Tuberculum Anterius.
3.—External nucleus.
4.—Cancellated layer.
5.—Corpus geniculatum externum.
6.— " " internum.
7.—Posterior nucleus of the Optic Thalamus.
From Ferrier, after Monakow.

FIG. 348.

less directly continuous with the tegmentum or the posterior one-third, the sensory division of the crura cerebri; and the cutaneous sensory tracts of the internal capsule are in connection with the optic thalami. The optic tracts, or continuations of the optic nerves, are connected with the pulvino-geniculate portion of the thalamus. The thalamus is also connected, by way of the pillars of the fornix, with the centers of smell, tactile sensibility, and probably taste, in the cortex of the cerebrum. It also connects, by means of the *corona radiata*, with the sensory occipito-temporal portion of the cortex. (Fig. 366, *T4.*) It also connects with the corpora striata, and is supposed to communicate through the frontal part of the cortex by fibres ending in the gyrus fornicatus (fig. 366, *Gf.*), and is connected with the region of the insula, and with the hippocampal region directly by way of the pillars of the fornix, or indirectly via the corpora mammillaria.

The optic thalamus is exclusively sensory, and is believed to have no motor functions at all. The stimuli that are condensed in it are forwarded to other centers, the corpus striatum, the cerebrum, and probably the cerebellum, and are, in these organs, transformed into motor currents. It is especially related to the visual tracts, but also receives and forwards sense impressions from all the sensory organs. This is proved by the fact that it is connected with all the sense centers of the cortex of the hemispheres, to which there can be no doubt it forwards its condensed and made up sense stimulations. Of the several roots of the optic nerve in each optic thalamus, the ones originating with the corpus geniculatum internum are not concerned in the sense of vision, since they do not undergo atrophy, as the other roots do when the eyes are destroyed. They are supposed to answer as a commissure. The

real visual roots are those in the geniculatum externum and pulvinar of the optic thalamus, and the anterior brachium of the corpora quadrigemina. (*Ferrier.*)

The optic thalamus, like the other ganglia and the cerebrum, cannot be normally stimulated by mechanical irritations. These simply injure but do not cause normal reactions. The galvanic current alone is competent to do this. When the optic thalamus is injured by mechanical irritations, derangement is at once caused in the centers of muscular co-ordination and equilibrium, and in the motor centers. A rabbit may lose its cerebrum and its corpora striata and still be able to maintain its balance, but if one-half of the optic thalamus be also removed, there is a loss of sensibility on the opposite side of the body, and the animal falls over toward that side. If both optic thalami be removed, the sensibility of both sides will be destroyed, but after the shock of the lesion is recovered from, some degree of co-ordination and equilibration will remain through the influence of the muscular sense, the medulla and cerebellum. If, without removing the cerebrum, an incision be made in one of the optic thalami, the animal keeps turning to one side in a circular manner. According to Schiff, the destruction of the three anterior fourths of this organ in rabbits, causes the movement towards the injured side, and the lesion of the posterior fourth towards the opposite side. Extensive disease of the optic thalamus or the corpus striatum of one side, produces hemiplegia, or paralysis of both sensation and motion on the other side. The same effect is produced usually by an apoplectic effusion of blood into the substance of either of these ganglia. (*Carpenter.*)

In the higher vertebrates, the optic thalami are condensing organs for all sense stimulations, which they forward to the cells of the corpus striatum and the cerebrum, and they therefore receive stimulation from all the external senses; sight, hearing, smell, taste, touch, and the muscular sense. There are no optic thalami in the lowest of the vertebrates, and but little development of it in any of the fishes. The function they perform for the higher mammals is of a far simpler nature in the fishes, and such as it is, it is performed, we may infer, by the other sensory ganglia. The corpora quadrigemina, which are largely developed in these animals, receive the optic stimuli and distribute them to the corpus striatum, the cerebellum and the cerebrum; the route to the latter being by way of the posterior edge of the crura cerebri, the part upon which, in the other vertebrates, the optic thalamus is developed. This tract is also the route to the cerebrum for all the other sense stimuli, unless the sense of smell be an exception, which, in the fishes, it probably is.

The pituitary and pineal glands, which, with their appendages, are parts of the thalamencephalon, are already developed in the fishes

So there is no reason to doubt that in the thalamencephalon of the fishes, such co-ordination is accomplished as their cerebral development requires, in the same way as it is by the optic thalamus of the more advanced vertebrates.

Monakow concluded, from experiments, that each "nucleus of the optic thalamus is related to a particular tract of the cerebral cortex. He concluded that the posterior nucleus (fig. 348, 7) is related to the basal regions of the hemisphere, the pulvinar and corpus geniculatum externum (fig. 348, 5) to the occipital visual region, the corpus geniculatum internum (fig. 348, 6) to the temporal or auditory region, the external nucleus (fig. 348, 3), and neighboring parts, to the upper and lower parietal regions, and the anterior tubercle and median nucleus (fig. 348, 2, 1) to the frontal regions of the hemisphere." It is too soon to be quite sure of these details. Further investigation and experiment is required. (*Ferrier.*)

According to Luys, the optic thalamus is divisible into four sections, each of which is related especially to the condensation of a special class of sensations. The anterior of these centers of sensation, is the ganglion of the olfactory sense, the second the ganglion of sight, the third that of touch and general sensation, and perhaps including taste, and the posterior ganglion that of hearing. There are many facts which support this subdivision of the optic thalamus. Hunter gives the case of a young woman, "who in three years successively lost the senses of smell, sight, hearing and sensation, and who gradually sank, remaining a stranger to all external impressions." It was found that the optic thalami alone had been affected, and they had been gradually destroyed by a fungus hæmatodes. Dr. Auguste Voisin tells of a case in which smell on one side was lost, accompanied by degenerations of the anterior ganglions of the thalamus. Serres reported a case of loss of sight caused by hemorrhagic effusion of the middle centers, or second ganglions. Luys observed two cases of loss of sensation on one side, accompanied by the destruction of the "median center," third ganglion, of the opposite side only; also in two cases of deaf mutes he found the trouble to be located in the posterior ganglions of the optic thalami, in one case a lesion, in the other an amyloid, or starchy degeneration of the parts. Luys is also of the opinion that stimuli reach the optic thalami from the visceral or vegetative organs, and are co-ordinated there like the stimuli from the senses and the cerebrum. When the co-ordination of the external stimuli takes place in the optic thalamus, without the intermixture of the memory stimuli from the cerebrum, the result is the automatic or instinctive sensori-motor actions. In man, this class of actions is not nearly so large relatively as it is in those animals possessing smaller development of cerebrum. Notwith-

standing the great influence memory stimuli have in our actions, however, there are still a good many of these sensori-motor movements, examples of which are the eyes closing to a sudden dazzling light; the start caused by an unexpected sound; sneezing, from excitation of the retina by a dazzling light, and of the pituitary membrane by an irritating substance, such as snuff; vomiting, produced by a loathsome object, a disagreeable smell, or a nauseous taste; sea-sickness and nausea, from swinging, teetering, and riding backwards; laughter upon tickling; yawning from uneasiness, arising generally from deficient respiration, but sometimes in the unconscious imitation of others doing the same thing; fidgets from an uneasy feeling in the muscles. In disease, especially nervous disease, there is much of this sensori-motor action. In hydrophobia, the sight, sound or touch of liquids, or even currents of air, are liable to excite the muscular contractions, and in many hysteric subjects the sight of a paroxysm in another is pretty certain to bring it on themselves. A hysteric case is cited in which a woman was liable to be thrown into convulsive movements, sometimes accompanied by an involuntary cry, by the slightest external stimulus of sight or sound, the shadow on a curtain of a passing bird, flickering of a flame in the fireplace, displacement of a portion of the wick of a candle, the rustle of a paper or rattle of a door lock. (*Carpenter.*)

"It may be affirmed with certainty, that no mental action can be originally excited save by stimulus of the sensations, and it is the office of the sensory ganglia to form these out of the impressions brought to them from the organs of sense, and to transmit such sensorial changes to the cerebrum. But they have a no less important participation in the downward action of the cerebrum upon the motor apparatus, for no voluntary action can be performed without the assistance of a *guiding sensation*, as was first pointed out by Sir C. Bell." The full significance of this is that our actions are so essentially and rigidly reflex that no movement of a single muscle can be made by the *guidance* of the will, or of the idea motor or cerebral stimuli. A direct and present sensation or stimulus from the periphery is necessary in every moment of muscular action. "In the majority of cases the guiding or controlling sensation is derived from the muscles themselves, of whose condition we are rendered cognizant by the sensory nerves with which they are furnished, but there are certain cases in which it is ordinarily derived from one of the special senses," and in which the muscular sense is not adequate alone to furnish the necessary stimulation.

It is impossible to make or sustain voluntary efforts without a guiding sensation of some kind. (*Carpenter.*) "Thus, in complete anæsthesia of the lower extremities without loss of muscular power, the patient is as completely unable to walk as if the motor nerves had also been para-

lyzed, unless the deficient sensorial guidance be replaced by some other, and in similar affections of the upper extremities, there is a like inability to raise a limb, or to sustain a weight. But in such cases the deficiency of the 'muscular sense' may be made good by the visual; thus the patient who cannot feel either the contact of his foot with the ground, or the muscular effort he is making, can manage to stand and walk by *looking* at his limbs; and the woman who cannot feel the pressure of her child upon her arms, can yet sustain it so long as she keeps her eyes fixed upon it, but no longer, the muscles ceasing to contract and the limb dropping powerless the moment that the eyes are withdrawn from it. Thus it is, too, that when we are about to make a muscular effort the amount of force" used accords with our conception of what will be required, as indicated by the experience of former sensations. If the estimate is wrong, we will exert too much or too little effort. The movements of the eyeball are directed by the visual sense (and not by the muscular sense) in the same way that most muscles are directed by their own muscular sense. When we close our eyes we cannot move them in any required direction without an effort that strongly calls forth the muscular sense.

The auditory sense governs the movement of muscles that are concerned in the production of vocal sounds. People who never heard a sound, cannot articulate, although they possess all the necessary muscles in good order. Through the visual sense, however, and long training, people born deaf have learned to talk imperfectly.

The muscular, tactile and visual senses are combined in the movements and balancing of the body. If a person be blindfolded he cannot walk straight toward an object at any considerable distance, because deprived of the guidance of the visual sense. A blind man can do much better, because his muscular sense is so much more acute by use, that it in considerable part, supplies the visual deficiency. "When our vision, however, instead of aiding and guiding us, brings to the mind sensations of an antagonistic character, our movements become uncertain from the loss of that power of guidance and control over them which the harmony of the two sensations usually gives." A person *feels* insecure when looking down a precipice. If he attempts to walk a plank elevated 50 feet in the air, his muscles become almost paralyzed, and he loses the power of equilibrium, although he could walk the plank with ease if it were on the ground. He may become dizzy and lose his balance if he attempts to walk a plank or foot-bridge over a running brook. The muscular sense alone is more reliable than when it is counteracted and confused by an unsteady and uneducated visual sense. So, in such situations, it is safer to look up, and ignore, as far as possible, the influence of vision. In somnambulism the subject is guided by the muscular

sense alone, the visual sense being in abeyance, and neither helping nor counteracting, and yet the somnambulist will often transverse the most perilous places with safety. The actions of hypnotic subjects are under the same guidance. In their case, hearing is not always cut off, but vision usually is. Yet they will write whole pages with accuracy, going over them to dot the i's and cross the t's. In this they are guided by the muscular sense.

The foregoing considerations in regard to the guiding sense, apply to the actions that are made up in the optic thalamus and the corpora striata, considered as a single complete machine; to the optic thalamus and the sensory and motor organs of the cerebral cortex, considered as another machine; and to the motor organs of the cerebrum in connection with the sensory cells of the cortex, and their independent connection with the external sense organs by way of the posterior one-third of the internal capsule and the posterior layer of the crura cerebri, considered as a third machine. For the idea formerly held, that all the sensory paths to the cortex of the cerebrum were through the optic thalamus, has been shown to be incorrect. The cortex possesses sensory connections with the periphery, independent of the optic thalamus, and motor connections independent of the corpus striatum. Another idea formerly maintained by some physiologists, was that the optic thalamus, with perhaps the corpora quadrigemina, constituted the only centers of conscious sensation. Observations on the effects of disease and experiment have shown this to be incorrect. (*Ferrier.*) Without doubt the cells of the cortex themselves are the seat of the sensations of the stimuli, the impact of which they receive, and, since the cerebral cortex is, in man, by far the largest and most complicated collection of ganglions, its importance as a center of consciousness, entirely eclipses all others. But it does not follow there are no others, and if there are, the optic thalami will certainly be included. The subject can, however, be discussed to better advantage further on.

Corpora Striata. The ganglia of the corpora striata are motor, they receive the afferent stimuli from the optic thalami, and send forth motor stimulations, which traverse the anterior strands of the crura cerebri, medulla oblongata and spinal cord, to the limbs, &c. It was formerly thought that these ganglia were instruments under the control of the cerebrum, and simply forwarded the motor results of the action of the hemispheres. But this is now found to be incorrect. The fibres which enter the corpora striata end there, and do not go on to the cerebrum at all, so that these ganglia are probably in themselves independent terminal centers, the same as the ganglia of the cerebrum. The motor strands which pass down from the cortex of the cerebrum, to and through the internal capsule, do not connect with the corpora striata, but go on

directly to the anterior pyramids of the medulla oblongata, and so on down the cord, showing the cortex to be independent of the corpora striata. It would appear, then, that the corpora striata, in conjunction with the optic thalamus, and perhaps other sensory ganglia, constitutes a complete brain, just as the sensory and motor ganglia of the cortex

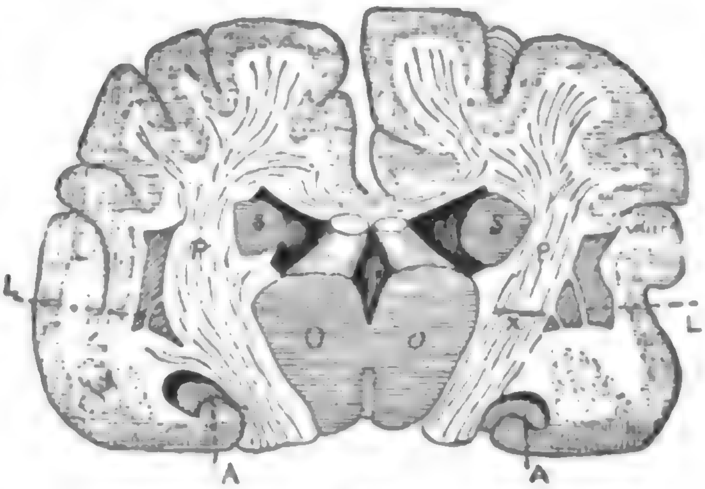


FIG. 349.—*Vertical transverse section through the brain of a Dog, on a level with the corpora mammillaria.* (*After Carville & Duret, Ferrier.*)
O, O. Optic Thalami.
S, S. Caudate Nuclei of the Corpora Striata.
L, L. The Lenticular Nuclei of the Corpora Striata.
P, P. Internal Capsule, or peduncular expansion.
A, A. The hippocampi.
X. Section of the posterior part of the peduncular expansion, causing hemianesthesia (loss of sensation) on opposite side of the body in Dog or Man.

FIG. 349.

do, though, of course, of a far less comprehensive kind. A mechanical irritation of the corpora striata does not produce pain or muscular movement, but when they are stimulated by the galvanic current, normal muscular action is the result. If one of the intraventricular ganglions, the nucleus caudatus, is electrically irritated, tonic contraction of all the muscles on the oppo-

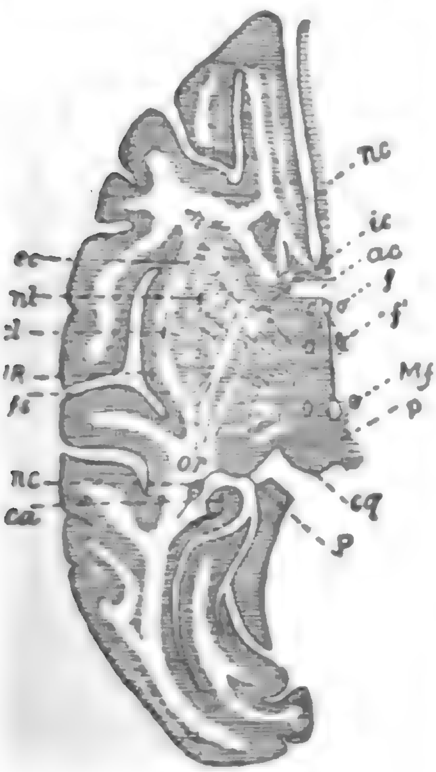


FIG. 350.

FIG. 350.—*Horizontal section of left hemisphere of Monkey, on a level with the anterior commissure.* (*Natural size.*) (*Ferrier.*)
ac.—Anterior commissure.
ca.—Cornu ammonis, or hippocampus major.
cl.—Claustrum.
cq.—Corpora Quadrigemina.
ec.—External Capsule.
ic.—Internal "
IR.—Island of Reil.
f.—Anterior pillar of Fornix.
f'.—Ascending fibres—vicq d'Azyr's bundle.
Mf.—Meynerts fasciculus.
fs.—Fissure of Sylvius.
nc.—Caudate Nucleus of Corpus Striatum.
nl.—Lenticular " " "
or.—Optic radiations.
P.—Pulvinar.
p.—Posterior Commissure.

site side, is the result. The experiments appear to prove that the motor connections of the corpora striata are exclusively with the decussating strands of the spinal axis, so that all its motor action is crossed.

Destructive lesions in the region of the corpus striatum, cause paralysis of motion on the opposite side of the body, but sensation is not affected. It is evident, however, that the functions of the corpus striatum, in regard to the motion of the limbs, may be assumed entirely by the cortex of the hemispheres, because as long as the cortex and its efferent connections, by way of the anterior two-thirds of the internal capsule, remain unbroken, lesions of

pus striatum alone may be recovered from, and no doubt the entire corpus striatum might be gradually removed by disease, and its functions assumed by the cortex without serious results. One-sided destruction of the corpora striata has more striking apparent effect on the lower animals than where both sides are affected alike. In the case of a rabbit, both of whose lenticular nuclei have been destroyed, the animal is not distorted or pulled out of shape, as where one side only is affected, but it will sit motionless and apparently apathetic. It can still leap and move in obedience to reflex irritation, but appears to have lost volitional control of its limbs; and this may happen while the cerebral cortex is entire, and it still possesses intelligence and desire. The animal might recover from this, however, although the corpora striata are of more relative value to the rabbit, whose smooth hemispheres have less relative influence, than to the higher mammals. If the corpora striata of both sides are removed, together with the front of the cerebrum, the animal stands in a stupor, quite bereft of ability or inclination to move of itself. If the internal capsules, which contain the sensory and motor tracts between the cortex and periphery, are destroyed, together with the corpora striata, the paralysis is permanent, and no recovery of voluntary motion is possible. The nucleus lenticularis is the larger and more important portion of the corpus striatum. The fibres from the nucleus caudatus pass through it, and injuries to it are more permanent in their effects than those to the nucleus caudatus.

It appears, on the whole, that the basal ganglia constitute a complete machine competent to run certain departments of the nervous economy independently of the cortex of the cerebrum. We have seen that the spinal cord, with its nerve fibres and ganglions of vesicular matter, forms a machine competent to turn a simple tactile impression into a muscular contraction. Its reactions are limited to those called reflex, and the impressions of sound, light, &c., do not enter into its combinations and co-ordinations. Next, the medulla oblongata appears of itself to be another such machine, and the cerebellum is a third. These two receive and combine a greater number of sensory impressions than the cord, and convert them into much more varied motor stimulations, giving rise to complicated, co-operative, muscular adjustments and movements. The basal ganglia constitute the fourth of these machines, and is of a higher grade than the others, because it is moved by a greater number and variety of stimulations, not only from the tactile and muscular senses, but from sight and hearing as well. Moreover, it is highly probable that a certain limited degree of memory enters into the combinations which make up the motor stimuli generated in the corpus striatum.

the interis still another center, the cerebrum, in whose combinations

between the nerve and the lens in front.[1] This sort of an eye is thus shown to have been the property of the earliest vertebrates, and it was single and median. It existed in the earlier reptiles, such as the ichthyosaurus and plesiosaurus, along with the bilateral eyes, and in the course of ages it has become superseded by them. This third eye was no doubt functional in the case of the labyrinthodont, a fossil amphibian, since there is a large orifice in its skull for the passage of the nerve from the pineal gland to the eye. More or less trace of the pineal eye is discovered in various reptiles, as iguanas, chameleons, flying lizzards, geckos, &c. Even in birds there is a rudiment of it, and a trace is to be found even in mammals. The pineal gland, which was originally the sensory ganglion of the median or pineal eye, persists very remarkably in all vertebrates except the very lowest. The pineal gland is therefore most certainly the remnant of a sense apparatus which formerly included an eye and a connecting nerve. The question arises, why, since the eye and the nerve disappeared so long ago, the corresponding piece of brain has not disappeared too. To my mind there is only one solution, and that is, that this piece of brain has remained functional. Its original office was to receive the sight impressions from the pineal eye, and in former times it must have constituted a relatively larger part of the brain than now. But this ganglion is connected with the rest of the brain, and no doubt undergoes waste and repair the same as the rest. In short, its function, although changed in detail, must still, to some extent, subserve a purpose similar to its original one. As the hand has been gradually modified from a fin by new habit and use, so I take it a new use has been gradually put upon the pineal gland. Its position and connections, as well as its pedigree, would indicate that its functions are sensory. It is single and median, which indicates that its functions are related to both sides alike. In all probability it is commissural between the two sides of the sensory tract of the crura cerebri, and helps to establish sensory equilibrium between the complementary halves of the corpora quadrigemina and of the optic thalami.

CHAPTER LXIII.

FUNCTIONS OF THE CEREBRUM.

The establishment of the true theory of the functions of the cerebrum of course necessarily overthrows any false theories which may have been entertained. Phrenology is one of these theories, and as it has gained wide acceptance, it may be well enough to point out the error of theory on which it is based.

The theory of the Phrenologists is, that the brain is the organ of the

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[1] See fig. 181.

mind and that different parts of the brain are the organs of different mental qualities. If any particular organ is large, it indicates that the faculty of the mind which corresponds with it is powerfully developed. Thus if the organ of acquisitiveness were large, the disposition would be to hoard up property, that is to acquire it for its own sake. If destructiveness were large, the disposition would be to mar and destroy and kill. If mirthfulness were large, the disposition would be to make fun. If memory were large, the person would not be forgetful. In short, the whole surface of the brain was cut up into patches, each patch being the representative organ of a corresponding faculty of the mind; and if any organ was undeveloped, it indicated that the corresponding faculty of the mind was deficient or wanting. Thus, if the organ of locality was deficient, the man would easily get lost, would not have the faculty of getting about, could not easily learn geography, &c.

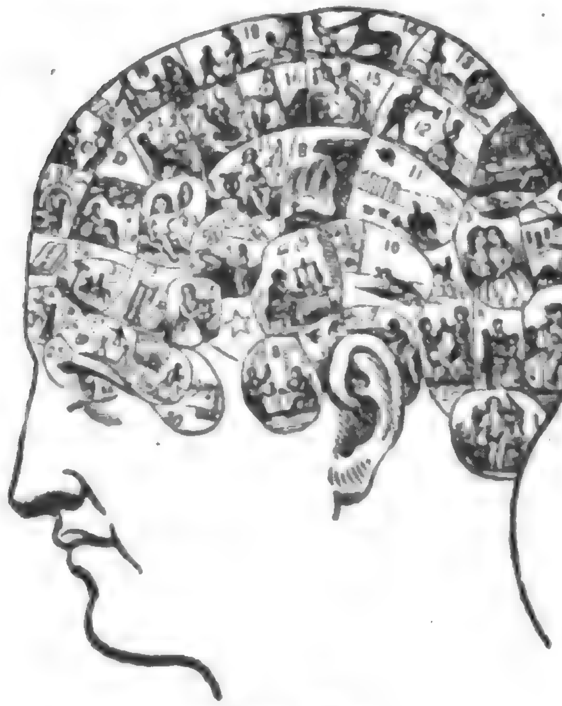


FIG. 353.

FIG. 353.—*Phrenological Chart.*
1 Amativeness; A Conjugal love; 2 Philoprogenitiveness; 4 Inhabitiveness; 3 Friendship; 5 Continuity; 13 Self-esteem; 12 Approbativeness; 14 Firmness; 15 Conscientiousness; 18 Veneration; 16 Hope; B Sublimity; 19 Benevolence; 17 Spirituality; 22 Imitation; 21 Ideality; C Human nature; D Suavity; 37 Comparison; 36 Causality; 23 Mirthfulness; 32 Memory; 31 Locality; 33 Time; 34 Tune; 24 Individuality; 26 Size; 27 Weight; 28 Color; 29 Order; 30 Calculation; 35 Language; 25 Form; 20 Constructiveness; 8 Alimentiveness; 9 Acquisitiveness; 11 Cautiousness; 10 Secretiveness; 7 Destructiveness; * Vitativeness; 6 Combativeness.

The cerebellum was held to be the organ of amativeness, and although it is separated from the cerebrum by the tentorium, just on the other side of the tentorium is conjugal love. This faculty depends largely upon amativeness, and on the chart is shown to be contiguous to it, while the two parts of the brain are anatomically severed. This appears to be a singular arrangement, but the arrangement of the boundaries of the other organs likewise ignores the geography of the convolutions and fissures. Some organs lie in two or more convolutions and some convolutions are divided by the boundaries of two or more organs. Of the 42 organs three only are definitely described in terms of the brain itself, Amativeness being assigned to the cerebellum, Alimentiveness to the anterior convolution of the middle lobe (*At* Fig. 342), and Language to the orbital convolutions (*S. or* Fig. 342). The rest are mapped out on the skull and it would be difficult to locate them with precision on the brain itself or on any two brains alike. (See fig. 353.)

To generalize, the intellectual faculties were located in the forehead.

the affections in the lower back-head, the executive powers in the lower side-head; and the moral, spiritual and religious sentiments in the top-head. This plan ignores the under surface of the cerebrum, and the two mesial or inner surfaces of the hemispheres, and takes no account of the brainy processes called the hippocampi which fill up the descending and posterior horns. (See Figs. 275, 276, &c.) About half of the convolutions, therefore, are left without anything to do, and all the business is assigned to the part that is visible and feelable. This will not do. The faculties have not been arranged with reference to their accessibility to the phrenologist's fingers. Among the earliest fissures developed is the hippocampal, and the inference is unavoidable that its functions are among the most important and ancient; but this system takes no notice of it at all. There is a certain method in the grouping of the phrenological organs by which those of related functions are made to stand near to each other. Thus we have weight, size and form; causality and comparison; human nature and suavity; ideality and sublimity; cautiousness and secretiveness; combativeness and destructiveness; amativeness and conjugal love; time and tune; locality and memory, &c. This grouping has a plausible appearance if we do not look beneath the skull. The list of organs is by no means long enough to accommodate all the qualities usually ascribed to the mind. Having an organ for benevolence, why should we not have one for selfishness, greediness or hoggishness? Why should not the organ of hope have its antithesis in an organ of despair? Self esteem its self distrust; mirthfulness, seriousness; acquisitiveness, prodigality? Why not oppose an organ of vagrancy to that of inhabitivness; fickleness to firmness; bluntness to suavity? Why not have an organ of practicalness, and another of visionaryness, one of conservativeness and another of progressiveness?

Perhaps it will be said that where there is an organ representing a positive quality, its want of development will indicate the predominance of its opposite quality; as for example if a person have not inhabitivness he will naturally tend to be a vagrant. That principal might apply in the case of some of the faculties, as for instance if the organ of form or that of color were wanting the person is simply destitute of the faculty of distinguishing details of shape or the shades of color. But a disposition to wander is often as positive an instinct as that of attachment to one spot. There are nomadic tribes both of men and other animals whose delight it is always to be on the move. A man might be indifferent to his locality and so deficient in inhabitiveness; yet from the very necessity of being *somewhere* he might stay all his life in one place. So selfishness is a positive quality, not perhaps very compatible with benevolence, but by no means certain to be present when the latter is absent. If a fat 300-pound hog be allowed access to a superabundance

of food, he will stuff himself far beyond the requirements of hunger and when uncomfortably full will lie down beside his trough. If now a hungry runt of a shote be admitted to the trough his greedy onslaught on the food will so stimulate the fat one, that he will with great effort scramble to his feet again, and regardless of his needs, his appetite or his comfort, recommence the stuffing process in competition with his lean rival and eat till exhausted in capacity and ability for further effort. This *hoggishness* is no part of acquisitiveness, but is a quality by itself. It prompts persons to scramble for that which they do not need and cannot use, merely to prevent some one else from having it.

Seriousness or gravity, too, appears to be as positive a quality as mirthfulness. There are people who delight in being long-faced and sober, and who regard a joke as a sort of crime. A simple deficiency in mirthfulness would result in mere indifference, but the faculty I speak of begets a positive aversion and disgust to levity.

But the fact is, the phrenological system is founded largely upon incorrect physical principles. It separates the function from its incidental qualities, and dignifies these qualities with the title of functions. Qualities are not *things*, athough they are inseparable from things. We can say of a stone it has hardness, but we cannot separate the hardness from the stone, and keep it in one place and the stone in another. The phrenologist locates the organ of *firmness* on top of the head; firmness in what? Firmness is a *quality* of something. It cannot exist in the abstract. A post set in the ground may possess firmness; there may be a firmness of muscle tissue or of bone tissue. But the firmness of the bone cannot occupy a position in the brain while the bone itself is in the leg.

Firmness is explained to mean "decision, perseverance." Now this decision must apply to something to be decided, and in order that *decision* or perseverance in regard to doing anything, be located in the particular spot designated for it, the *faculty* for doing that thing must be located in the same place. Decision and perseverance are qualities which attach themselves in a greater or less degree to everything we do. The phrenological organ of individuality is said to prompt us to "observation," but we cannot observe or investigate, or wish to do so, except with *some* degree of decision and firmness. Firmness, so far as it relates to the function of observation, either in the simple consciousness of an inclination to observe, or in the motor action necessary to accomplish an observation, must be looked for in the organ of individuality itself, if there be such an organ. As the size of a muscle, other things equal, is supposed to indicate its strength, so the size of an organ ought to show the power, force, decision and perseverance with which it can be made to act when stimulated by the appropriate motive.

Again, combativeness is said to be the organ of "resistance, defence." It is as impossible that there should be such an organ, as that there should be an organ of strength. Men resist some things, and succumb more or less easily to others. The strength of resistance depends upon various conditions; one is the hopefulness of success. Men will seldom fight when they are convinced that they will be defeated. This includes a knowledge of their own strength, and an estimate of the probable force they are required to overcome. So that the question of resistance in any given case depends upon action of a varied and complicated kind, involving a considerable number of intellectual faculties. A man who, in the presence of the timid and helpless, is an arrogant bully and tyrant, is liable in a different and more robust presence to subside into an arrant poltroon.

Destructiveness, too, is based upon conditions. A hungry lion will invade a flock of sheep, and taking one for his dinner will slay and eat it. But he will not wantonly kill the rest just because he has large "destructiveness." The most timid man or woman would act in the same way. The motive for killing being the same in the two cases, its execution will depend upon the ability, in muscular force or cunning, of the individual, and unless the motive of hunger and the *ability* reside in the organ of destructiveness, that organ can be no indication of what sort of action will result.

An analysis of the so-called mental functions easily shows them to be composite, and they are all remotely or directly dependent upon physical conditions. Conjugal love, or a desire for a life union, evidently depends upon several conditional and supporting propensities, as amativeness, philoprogenitiveness, inhabitiveness and friendship. If there are four independent functions such as these, conjugal love and marriage will necessarily follow, whether there be an organ of conjugal love or not.

Secretiveness or slyness arises only in the case of animals whose weakness requires them to steal that which they are unable to take by force, or whose slowness prevents them from overtaking their prey in an open race. Grazing animals are not sly because their food never tries to escape them. Cautiousness is a quality akin to secretiveness. It is developed in any animals exposed to danger. Plainly, natural selection must have always operated to eliminate the fool-hardy and the too venturesome, and thus to preserve the cautious and wary.

The faculty of color depends upon the development of the retina with its rods and cones, and there can be no such faculty in the absence of a perfect external organ of color. So tune depends upon the perfection of the ear, the external organ of sound. Phrenology locates the organ of form between the eyes, the distance of the eyes from each other indicating the strength of the faculty. Some writers who oppose

phrenology, admit that persons whose eyes are far apart have a better idea of form, but they ascribe it to the fact that such persons possess a more complete power of seeing around objects after the manner of the stereoscope, so that the image of an object is more complete and life-like than it is to others whose eyes are close together.

"Weight," or the ability to balance and judge of the comparative weight of objects, depends upon the cultivation of the muscular sense. All the perceptive faculties depend directly upon the sense organs, and obviously could not exist without them.

Such a propensity as alimentiveness, "appetite, hunger," must originate in relation to the body to be fed. If alimentiveness is to be regarded as the organ of taste its function must depend upon the delicacy and number of the taste papillæ upon the tongue. Where there are no papillæ we have reason to believe there is no perception of taste. But animals without any delicacy or even perception of taste, nevertheless, have enormous appetites. Such appetite arises from the state of the stomach. All animals eat, and eat enough, brains or no brains, organs or no organs.

Very important qualities of character depend upon the sexual glands which are therefore proved to be real organs in the phrenological sense. The castration of animals reduces their force and renders them comparatively mild and gentle, and the same effect is produced on men by this operation. D'Escayrac de Lauture reported that six adult slaves of the Kachef of Abouharas in Kordofan were emasculated for having conspired against their master. They all survived the mutilation, but their characters were completely changed, and all rebellion was effectually taken out of them. Godard who reports the above adds that according to Dionis, "castrated persons are unsociable, liars and rascals, and that they never seem to practice any human virtue; and that according to Benoit, Moju ennuchs are the vilest class of the human race, cowards and rascals because they are weak, envious and spiteful because they are unhappy." Persons born without testes are weak and timid, blush easily, are easily frightened. (Luys.)

If we consider the intellectual faculties, we find they are all equally dependent upon physical bases. The observation of external objects must be through the sense organs, not indeed by means of anything such organs do, but by what is done to them by external forces. The perception of objects implies a perception of their relationships to each other, or at least some of their relationships. The greater the number of these which make their impression, the greater the intellectual capacity of the individual. As this capacity is allowed by all, including the phrenologists, to be in proportion to the number of the brain cells involved in the action, it is at least antecedently probable that the intellectual action begun in the shape of material forces, remains material to the end. At all events

the dependence of causality and comparison upon external stimuli will not be denied. They are nothing more than a subdivision of perception. They are nothing more than the collateral extension of the perception of single objects, since the perception of one object implies the ability to perceive another and another. The perception of a space or an intermediate object between two others *is* the perception of a relationship and by so much an act of reason. It can be shown that all reason consists merely of an extension of this simple perception. Causality and comparison are principal divisions of the general faculty of the perception of things in their relations to each other. Human nature or the perception of motives is a special branch of the same faculty. Mirthfulness, the phrenological name for wit and humor, designates another branch of the intellectual perceptions. The ability to see the point of a joke involves comparison.

According to phrenology the organ of memory or eventuality occupies a comparatively small patch in the middle of the lower part of the forehead. When we reflect that not a single mental function can be carried on without memory, this arrangement which confines memory to an insignificant area appears unaccountable.

The organ of calculation is placed on the side of the temple in line between the ear and the eye and near the latter. In order to calculate, one must use the multiplication table. As this is simply a series of dry "facts," I suppose their memory should be recorded in the organ of eventuality. But it is easy to show that the whole process of calculation consists in the revival of the memories of certain various relations in which numbers stand to each other, which relations have been ascertained in the past. These relationships are matters of fact, and the principle by which they are remembered cannot differ in any essential respect from any other memory. Calculation must therefore be an organ of memory or else it is no organ at all. The same reflections obviously apply to every other faculty. They all involve memory except where they are instinctive and are exercised for the first time. How, for example, can a person feel the sentiment of benevolence except in connection with some object towards which the feeling is exercised; and how can such object be recognized as such, except by an act of memory? According to the dynamical theory the sight of the object awakens the memory, and the memory awakens the feeling; so that in reality the organ is an organ of memory and its stimulus originates without and not within.

It is indeed antecedently probable that certain definite tracts of the brain are endowed with specific functions, and have their connections and relationships with definite parts of the body. We inherit from our ancestors definite forms of limbs, muscles, vital organs and organs of

sense, and with slight variations these parts have been handed down from remote generations. It is perfectly reasonable to suppose that the nervous connections between the members and the brain are as definite and constant as the other parts are, and this probability is confirmed by the facts of comparative anatomy, as far as they have been ascertained.

Furthermore, it is reasonable to infer that the same parts of the brain are connected with their same corresponding muscles, glands, sense organs, &c., now as in the generations gone by. The existence of organs in the brain, therefore, is antecedently probable, but more than that it is experimentally proved, as will be seen further on. But the nature of these organs is very different from that assumed by the phrenological philosophy. As assumed by that system, the brain is the organ of the *Mind*; as proved by scientific research it is the organ of the *Environment.*

In the simplest animal forms there is no perceptible nervous system. The animal is moved by external stimuli directly applied to move the whole body of the infinitesimal animal, or some part of him. When, by evolution, the animal attained such a size that a stimulus applied on one side was too far away to affect the opposite side by direct contact, the stimulus made for itself a pathway across the body of the animal. This pathway constitutes the earliest form of the nervous system, but it involves the entire principle upon which all the subsequent developments of it are founded. No matter how extensive and complicated the nervous system becomes, it is never anything more than a pathway between the body in the environment from which the stimulus is projected, and the muscle which is adapted to be moved by it. The fact of the immense development of the brain as a part of this pathway, does not alter the principle. The development of the brain has come about by the great number and variety of the stimuli on one side, and the great number and variety of the muscular movements possible on the other. The brain may be compared (remotely) with the central office of a city telephone system. If there were but two subscribers to the telephone, no "central" would be required. But when there are three, a simple ganglion of switches is necessary to shunt the message and enable one to communicate with either of the others. This shunting arrangement, acting under the direction of the sender, no matter how many subscribers, never becomes anything more than an inserted adjunct in the pathway of communication, qualifying the pathway but in no manner affecting the message. The comparison is general, and is incomplete in important particulars. The body is a community of parts having general identical interests. The stimuli from different parts and from the environment, meeting in the brain, modify, neutralize and reinforce each other, so that the stimulus, starting from any given source, may reach a different muscle and accomplish a different motor action from what it

would have done if the brain had been different or absent. But the passage of every stimulus into the brain modifies it, and renders it liable to offer a different reaction against subsequent stimuli. In this respect the central organ may be compared to a bar formed in the bed of a river by the deposit of alluvial matters, which thereafter deflects and arrests the current by which it was created.

There are two crises in the passage of a stimulation from the external sense organ to a muscle; the first, when it reaches the brain, arousing sensation and encountering the modifying action of other stimuli; the second, when the modifications are completed and it reaches the motor nerve on its way to the muscle. It is evident that with many stimuli this second crisis is not immediately reached, and perhaps never, but that the stimulus is neutralized by an opposing one, and reduced to heat, or expends itself in the modification of cells, which thereafter occupy a position of potential energy ready to unwind and exert a modifying influence upon some future action.

Experiments prove that there are real organs in the cortical cells, endowed with the functions of the two crises above mentioned, one set placed at the functional entrance, as it were, and receiving the first onset of the stimulus, and the stamp and modification which it imposes; and another set placed at the exit of the stimulus, which leaves upon them its stamp and the index of its motor destination. All incoming stimuli, such as sight, sound, touch, taste, &c., affect the first class of cells, and when they are destroyed, the memories of these various incoming sense stimuli are lost. All motor stimuli going out to move a hand or foot, an eye or the tongue, leave their impressions upon cells of the second class, and when such cells are destroyed, the memory of the motor actions registered there, and the ability to repeat them, perish with them. They may be termed, respectively, the Initial and Terminal organs of the Cortex. The existence of these two sorts of organs is ascertained experimentally with a reasonable degree of certainty, and they are such as we might reasonably expect in view of the source and nature of the material energies concerned in their differentiation. Each form of energy modifies a patch of cells in its own peculiar way, and any subsequent stimulation of such cells renews a sensation of that particular kind of energy, as light, sound, contact, &c. Such patches of cells are, respectively, organs of light, sound, contact, &c. These are the organs of the first class. Those others of the second class are organs *for* and preliminary to muscular motion, but they, as well as the others, are differentiated and operated by the same external energies now transmuted into new forms by their action upon each other in their passage through the ganglions.

It is obvious that in every advanced brain between the two classes of

organs above mentioned, viz., the initial and the terminal, there must be a vast number of connecting intermedial organs. The energy in its passage across the brain encounters and differentiates such of these organs as lie in its path, and perhaps is itself entirely absorbed in the process. It is at least often modified and more or less deflected by its reactions from such organs.

The intermedial organs constitute the great body of the internal senses, to be described further on, with the predispositions put upon them by heredity or habit. And they bear the bulk of the impressions of education, experience and reflection; and the reactions from them taken together constitute the character. These intermedial organs are usually the immediate modifyers of the motor actions by directing the stimulation upon the terminal or motor cerebral organs. The muscular expressions, therefore, which are set up through these last, must correspond generally with the predispositions of the intermedial organs, and if we can give them a proper interpretation they become an index of the character. The method of reading character by observation of muscular expression is common to almost all men and animals. A tree is known by its fruits, and even a horse or a fish will read a man's character in part by his actions. But this sort of reading requires time enough to see the actions performed. If we could see the organs of the terminal class, or those from which the muscular actions are immediately stimulated, they would show by their size the amount of work they do, and consequently the relative activity of the muscles subject to their stimulation and we could thus read the character upon the same general principle as by watching the effects of the stimulation upon the muscles of expression over a term of years. We say of a person who laughs readily that he is jolly. If we do not see him laugh, but could see the cerebral organ which governs the stimulations of the muscles engaged in laughter, we should know from their size that they were in frequent activity and that the man was jolly. Furthermore, if such organ lay on the external part of the brain and underneath a thin portion of the skull, there is nothing violent in the supposition that there might be a bulge or prominence in the skull over that organ, which would give a skilful manipulator an intimation of the relative importance and activity of such organ. To this extent, then, it is reasonable to say bumpology might go. Those faculties which have pronounced muscular expression might be read in brain prominences provided such prominences were accessible, and provided further, that such expressions were exclusively the result of such faculties. For example, there are cells which control the muscles by which a man takes off his hat. Suppose these could be found on the external surface of the cerebrum ; the phrenologist

See Pop. Sci. Mo., Aug., 1890.

might announce that this man takes off his hat; but what is there to show the motive which arises in the intermedial cells? Is it politeness, or the force of habit and drill? or because his head is too warm?

A study of comparative anatomy shows that the cerebrum is by no means one of the original vital organs. It is not possessed by the invetebrates except in a few of the highest which seem to be transitional between the vertebrates and invetebrates; and so it is not to be considered even as essential to a certain considerable degree of the nervous co-ordination and condensation which we denominate mentality. It is likewise very limited in extent and function among the lowest of the vertebrates, in fact, not appearing at all in the amphioxus. It is a comparatively lately added organ reinforcing and assisting the essential organs that were established before it.

In adult man the cortical or gray matter is usually about one-fifth of an inch thick, varying somewhat at different periods of life. It is thickest and the fissures are deepest in middle age. In infancy and old age the fissures are fewer and simpler, and the cortex thinner.

The fibres in the cerebrum, which radiate from the optic thalami and corpora striata to the cortex, are commissural only, and terminate in the cells of the cerebrum at one end, and those of the thalami and striata at the other. They connect in cells and ganglia with other fibres which continue down the crura cerebri to the periphery of the body. The anatomical relation which the gray matter of the cerebral cortex bears to the basal or central ganglia, precisely corresponds with that borne by the retina, which is only an expansion of the same substance as the cortex, as shown in the development of the eye; and the radiating fibres are in the same relation as the optic nerve. In the development of the embryo, the cortex originates by being detached from the corpora striata on each side, and the retina by being detached from the optic thalamus. Each is gradually pushed away from the place of origin, the connecting commissural nerve fibres elongating to suit. They are both sensitive to appropriate stimulations, the retina to those of light, the cells of the cortex to those originating in the environment, light, sound, contact, smell, &c., and also those arising from the agitations of other cortical cells.

The cerebrum, like the other great departments of the ganglionic central system, has its sensory connections direct with the external sense organs, from which it receives directly or indirectly all the stimulations by which it is moved and operated, and it also has its own direct motor connections with the various muscles of the body, and many of the glands. It has been shown that the spinal cord is by itself a complete machine for receiving a stimulus from the external sense organs, and forwarding it to a muscle, and that the medulla oblongata, the cerebel-

lum and the basal ganglia, constitute three other such complete machines. The same is equally true of the cerebrum. Its motive power, like that of a muscle, is furnished by the consumption of its own tissues, the loss of which is made good by the blood; but the stimulations which come to it from the environment furnish the disturbance which is

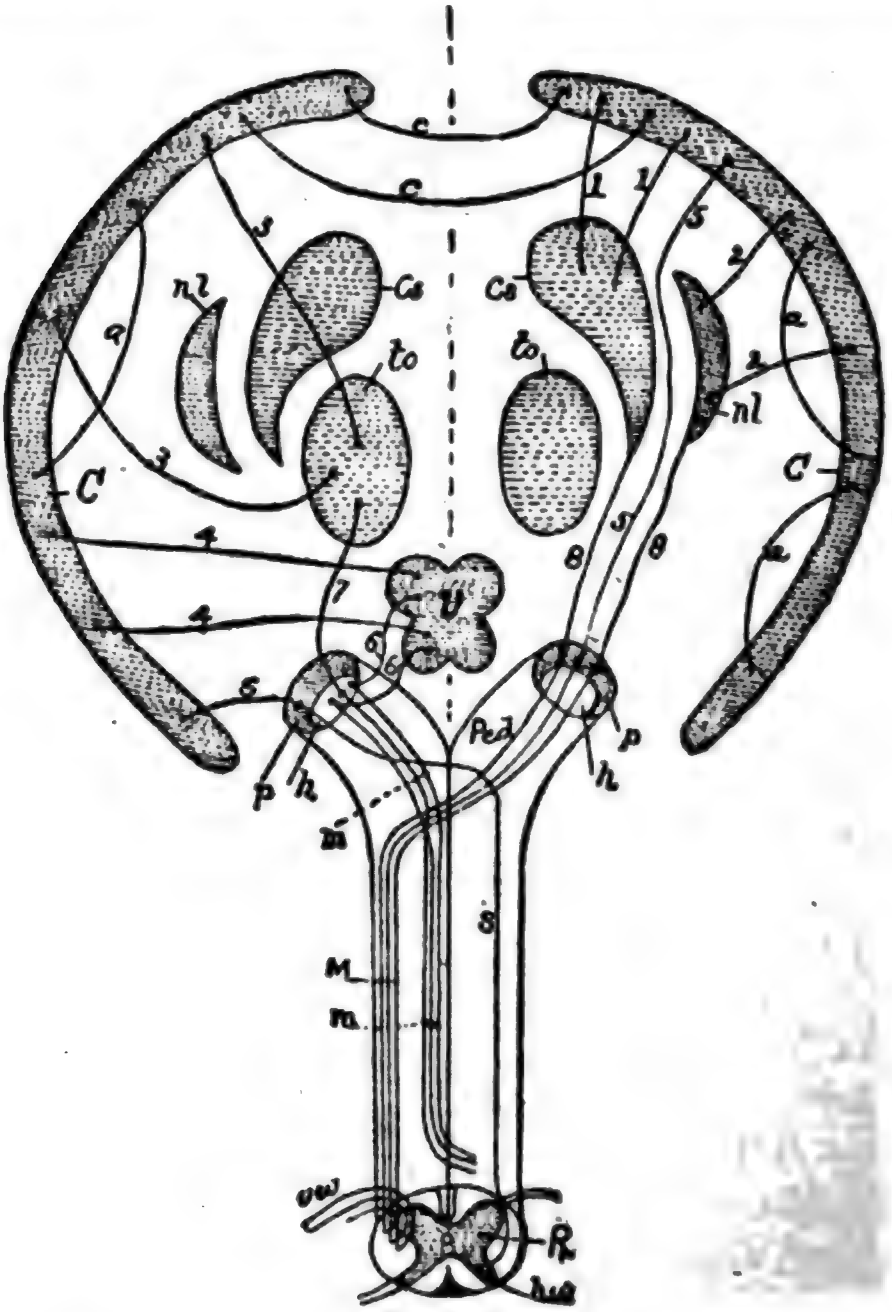


FIG. 354.

FIG. 354.—*Scheme of the Brain.* (*Meynert.*)

C C.—Cortex of Cerebrum.
Cs.—Corpora Striata.
to.—Optic Thalamus.
nl.—Lenticular Nucleus.
v.—Corpora Quadrigemina.
Ped.—Peduncles, or Crura Cerebri.
p.—Crusta.
h.—Tegmentum.
R.—Section of Peduncles (or cord)
vw.—Anterior roots.
hw.—Posterior "
1, 1.—Corona radiata of Corpora Striata.
2.—Corona radiata of Lenticular Nucleus.
3.— " " Optic Thalamus.
4.— " " Corpora Quadrigemina.
5.—Direct fibres from the Cortex.
6.—Fibres from the Corpora Quadrigemina to the [Tegmentum.
m.—Continuation of these.
8.—Fibres from Corpus Striatum and Lenticular Nucleus to the Crusta of Peduncle.
M.—Continuation of these.
ss.—Course of sensory fibres.
7.—Sensory fibres to optic thalamus.

necessary to set this motive power in action, precisely as the same sort of stimulations set off the reflex action of the spinal cord. Meynert's diagram, fig. 354, shows very well the relationships of the different parts of the brain to each other, and the course of the stimulations. Direct afferent fibres pass from the posterior part of the peduncles of

the brain, and from the sense organs, direct to the cortex, the Corpora Quadrigemina, the Optic Thalamus, &c., and direct efferent fibres run from the cortex, the corpus striatum, &c. It has been proved by the experiments of a dozen competent physiologists, that the motor nerve fibres leading down from the cortex of the brain are special tracks of stimulation between the cells of the cortex and particular muscles. For after the cortex has been removed, and the stimulating galvanic electrodes applied to the medullary fibres beneath, the same motor effects are observed in the muscles of the limbs that would have taken place if they had been applied to the cortical cells. These nerves "stand to the cortical matter precisely in the same relation as the anterior spinal roots do to the anterior horns of the spinal cord." (*Ferrier.*) This analogy extends to the effects of disease in the two regions. "When the anterior horns of the spinal cord are diseased (as in anterior polio-myelitis), or the anterior roots are divided, the motor nerves, in the course of four or five days, entirely lose their excitability, and undergo complete degeneration." Likewise it was found that after the gray matter of the cortex was removed, the motor medullary fibres which were at first excitable, in four or five days lost their excitability, and it has been shown that after destruction of the cortex alone, degéneration takes place not only in the fibres of the corona radiata, but in their continuations down the pyramidal tracts of the medulla oblongata and the spinal cord.

When the motor centers in the cortex of the cerebrum are destroyed, such destruction is followed by degeneration of the pyramids in the medulla oblongata, the degeneration taking place above the decussation of the pyramids on the same side on which the cortical injury has taken place, and on the opposite side below the decussation. This indicates that the pyramids contain the motor fibres which carry the stimulations made up in the cortex, including those constituting the will.

I quote below from Carpenter's comments on the experiments of Dr. Ferrier in stimulating the action of the brains of live animals by means of an interrupted galvanic induction current which could be increased or diminished at pleasure, and which was usually no stronger than could be borne without much discomfort on the tip of the tongue. It was commonly necessary to increase the strength of the current after the partial exhaustion of the nerve fibres by continuous stimulation in any one spot. But after such exhausted place was allowed to rest awhile it would recover so that it could be stimulated again. Dogs, cats and rabbits were operated upon and they were first chloroformed to render them passive and unconscious. A part of the skull was then removed so as to expose portions of the brain to view and the electrodes of the coil were applied directly to the surface of the cortical matter of the

brain. The first effect of the electrical stimulation is hyperæmia, or an *increase of the blood supply* to the part affected, which is seen in the swelling of the arteries and the deepening of the color. Second, it is shown that brain work has been done because there is a profuse flow of *venous blood from the sinuses* (large veins), which had been exposed in the process of uncovering the brain, but which had ceased to bleed before the application of the galvanic shock. When through continued hemorrhage the supply of blood was too much reduced to show signs of continued pulsations, the current however strong failed to stimulate.

When the two electrodes were placed on the cerebrum at some distance apart, the stimulation resulted in convulsions, and the further apart they were the more severe the convulsions. These fits were always preceded by a hyperæmic condition of the cortex of the cerebrum, "and not only was there in every case a distinct interval between the application of the electrodes and the first convulsive movement, but there was occasionally a distinct interval of time *after* the *withdrawal* of the stimulation, before the condition of the gray matter had reached the pitch of tension requisite for an explosive discharge. This of itself is sufficient to show that the effects were not due to conducted currents or *direct* stimulation of the motor nerves of the muscles, but to an abnormal excitability or irritability of parts whose function it might be inferred was to initiate those changes which would result in the normal contraction of the muscles affected." (Carpenter.)

In other words the galvanic stimulus acted upon the cortical motor cells in such a way as to take the place of the ordinary stimulus from the *internal* senses, or cerebral memory organs. For, as the experiments prove, a part of the cortex is made up of organs for receiving, and others for elaborating or co-ordinating external sensations; and these constitute the organs of the internal senses. Other cortical tracts appear to be the starting stations for motor stimuli which pass thence down to the medulla oblongata and on out to the muscles. The stimuli which start here are made up in the internal sense organs, although their elements are derived originally from the environment through external senses. When these same tracts are irritated by an interpolated stimulation at all like that which they are accustomed to, they will react in the usual way and produce the same motor acts. It has been shown that the galvanic stimulation applied directly to muscles and to motor nerves produced normal action, and the inference from all the experiments seems to be warranted that the normal stimulation conveyed by the sensory nerves is *exceedingly like* a galvanic interrupted current. Carpenter observes that the ordinary circulation of the blood is sufficient "to keep up the tension of the ganglionic centers to the point required for motorial discharge by automatic or volitional closure of the circuit,"

while "the higher state of tension induced by hyperæmia is itself sufficient to produce *spontaneous* motorial discharges." What this amounts to is, that when to the ordinary nervous tension constantly maintained by the ordinary circulation of the blood is added a conscious motor will, or an unconcious automatic stimulus, motor results take place; and so they do when this ordinary circulation is artifically stimulated to become an extraordinary circulation or hyperæmia. And so we find that in the production of motor results an extra access of blood acts in the absence of a will; and this leads us to the same conclusion which we shall reach by other routes, that the action of the will is to *create* this access of blood, and that it therefore stands in the same place in the chain of causes as an automatic stimulus, or as an artificial stimulus like that of Dr. Ferrier, and that its office simply is to determine to some special point an accession of blood; that is, to produce a hyperæmia. That the action is due to hyperæmia and the stimulation of the cells, and not to the direct stimulation of the motor nerves, is proved by the delay in the effects after the application of the electrodes, and by the persistence of the effects after the electrodes have been removed. It must be then that the stimulations of the cerebral cells in these experiments produce in them the same interaction, resulting in the same motorial discharges that take place ordinarily in consciousness. The motor actions are by the metaphysicians usually set down as the expressions of mental states. We can now say with confidence that the so called "mental state" is produced by the artificial stimulation of the cerebral cells, while the animal is stupified by chloroform. The movements which are called forth are often of the most complicated nature and are frequently those which particularly indicate strong emotions and ideas.

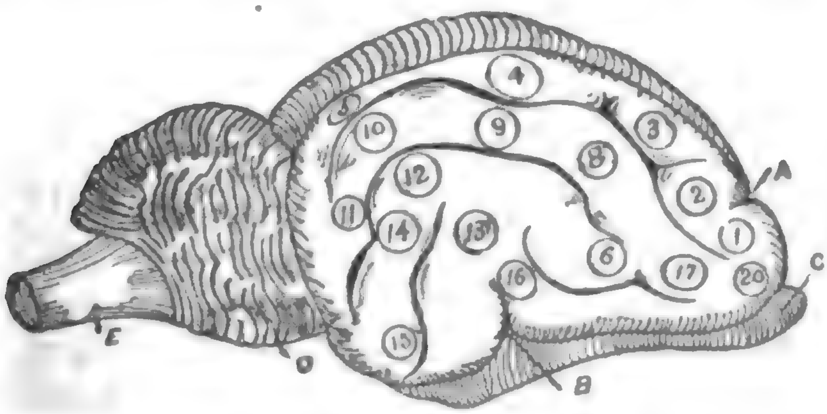


FIG. 355.

FIG. 355.—*Side view of Brain of Cat.*
A.—Crucial Sulcus dividing anterior convolutions.
B.—Fissure of Sylvius.
C.—Olfactory Lobe.
D.—Cerebellum.
E.—Medulla Oblongata.
The figures indicate points stimulated by the induction current in Dr. Ferrier's experiments. See text for explanation.

"Thus, in a cat the application of the electrodes, at point 2, fig. 355, caused the elevation of the shoulder, and adduction of the limb, exactly as when a cat strikes a ball with its paw;" at point 4, immediate corrugation of the left eyebrow, and drawing downwards and inwards of the left ear;" at point 5 "the animal exhibits signs of pain, screams, and kicks with both hind legs, especially the left, at the same time turn-

ing its head round and looking behind in an astonished manner;" at point 6, "clutching movement of the left paw, with protrusion of the claws;" at point 13, "twitching backwards of the left ear, and rotation of the head to the left and slightly upwards, as if the animal were listening;" at point 17, "restlessness, opening of the mouth, and long continued cries as of rage or pain;" at point 18 (on the underside of the hemisphere, not shown in the figure) "the animal suddenly starts up, throws back its head, opens its eyes widely, lashes its tail, pants, screams and spits, as if in furious rage;" at point 20, "sudden contraction of the muscles of the front of the chest and neck and of the depressors of the lower jaw, with panting movement." "Similar results were so constantly obtained, with variations obviously depending upon the degree of excitability and the strength of the stimulus, that the localization of the centers of these and other actions was placed beyond doubt; the movements of the paws being centralized in the region between points 1, 2 and 6, those of the eyelids and face between 17 and 8, the lateral movements of the head and ear in the region of points 9 to 14, and the movements of the mouth, tongue and jaws, with certain associated movements of the neck, being localized in the convolutions bordering on the fissure of sylvius (B), which marks the division between the anterior and middle lobes of the cerebrum; the center for opening the mouth being in front of the under part of the fissure, while that which acts in closure of the jaws is more *in* the fissure." These deductions in localizing the centers of muscular movement, cannot be accepted as conclusive except upon confirmation by facts of a different kind. Thus, when the animal starts up, throws back its head, opens its eyes, lashes its tail, pants, screams, spits, &c., when stimulated at point 18, it does not follow that point 18 is the center for the various muscular movements of head, eyes, tail, &c., because we know that there are many localities in the regions of the internal senses, the agitation of which might lead to motor action. Any purpose is founded, in greater or less part, upon compounded memories, it may be of sight, sound, or some other sense, or upon relationships among external things, the perceptions of which constitute sensations of intermedial degrees, and when formed are registered as such in some department of the internal sense region. It may be that No. 18 is such a point registering these condensed perceptions. From a point thus agitated the stimulus, if excessive, would overflow to motor nerves, and muscles would, by their motion, give "expression" to the agitated state of No. 18, for example. We commonly say that the screaming and spitting of a cat *indicate* rage. Rage, then, is, in essence, the name we give to the molecular agitation of a certain patch or combination of cortical cells. We know nothing objectively of rage except by its muscular expres-

sions, and seldom think of its intimate nature or antecedent cause. If we should trace these we should find its intimate nature to be the molecular activity of certain cells, and its antecedent cause whatever form of force stimulates these. And we are at liberty to affirm that the cat, in Dr. Ferrier's experiment, was as truly in a rage under the influence of a galvanic stimulus, as when in a state of consciousness it gave vent to the same "expressions" upon the too near approach of a dog. Since different objects and combinations of stimuli will produce rage in a cat, it must be that there are various patches, presumably in different parts of the cortex, the stimulation of which will produce rage and its motor expressions, seen in the glaring eyes, erected fur, spitting, and elevated spine. Experiments many times repeated, and compared with those of Munk, Ecker, and others, led Ferrier to adopt the conclusions in regard to cats which are shown in fig. 356. On comparison it will be seen that there is little or no disagreement between this and fig. 355.

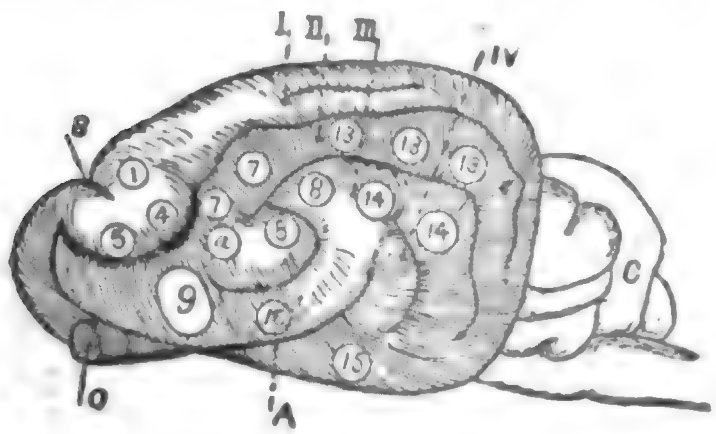


Fig. 356.

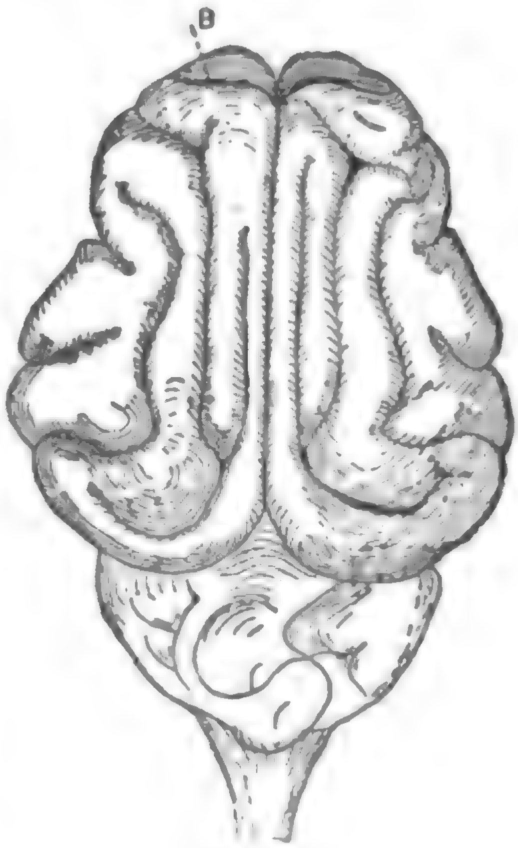


Fig. 357.

Fig. 356.—*Left Side view Brain of Cat.*
Fig. 357.—*Top view Brain of Cat.*
I.—First external convolution.
II.—Second " "
III.—Third or supra sylvian convolution.
IV.—Fourth or sylvian convolution.
A.—Fissure of sylvius.
B.—Crucial sulcus. 15 on the uncinate gyrus.
C.—Cerebellum.
O.—Cut end of the olfactory tract.
1.—Governs motor action of hind leg in moving forward.
4.— " " " " opposite fore leg in retraction and adduction, rapid, as if striking a ball.
5.—Elevation of shoulder, with flexion of fore-arm and paw.
a.—Protrusion of claws and clutching and grasping with paw.
7.—Motion of mouth and cheek, with closure of eye.
8.—Elevation of angle of mouth. Ear drawn down and forward.
9.—Motion of mouth and tongue; exhibition of rage—spitting and lashing tail.
13.—Eyeballs move to opposite side, also motion of head.
14.—"Pricking up" of ear, sometimes head and eyes move to opposite side.
15.—Elevation of lip, and torsion of nostril on same side.
16.—Divergence of lips in opening mouth.

From some of the earlier experiments on Dogs the following results were obtained. "When the electrodes were applied at point 9, fig. 358, the tail was moved from side to side and ultimately became rigidly erect." Within the circle 10 the application "elicited only cries as if of pain." At point 14 a continued application gave rise to the following remarkable series of actions: "It began with wagging of the tail

and spasmodic twitching of the left ear. After the cessation of the more violent spasms, the animal held up its head, opened its eyes wide with the most animated expression and wagged its tail in a fawning manner. The change was so striking that I and those about me at first thought that the animal had completely recovered from its stupor. But notwithstanding all attempts to call its attention by patting it and addressing it in soothing terms, it looked steadfastly in the distance with the same expression and continued to wag its tail for a minute or two, after which it suddenly relapsed into its previous state of narcotic stupor."

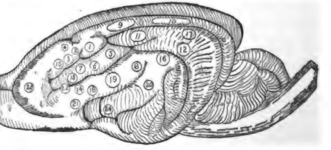


FIG. 358.

FIG. 358.—*Side view of Brain of Dog*, showing points stimulated in Ferrier's experiments. For explanation of figures refer to text.

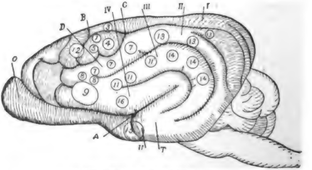


FIG. 359.—*Side of Brain of Dog.*

I, II, III, IV.—First, Second, Third and Fourth Convolutions.

A.—Fissure of Sylvius.

B.—Crucial, or Frontal sulcus,

O.—Olfactory Lobe.

C.—Coronal fissure.

D.—Coronal gyrus.

T.—Temporal lobe.

1, 4, 5.—Are on the *Sigmoid gyrus.*

15.—(U) Uncinate gyrus.

1.—Region of motor control of hind leg, advanced in walking.

3.— " " " tail, wagging sideways.

4.—Center for retraction and adduction of fore leg.

5.— " " shoulder, elevation and forward extension. Directly under 4 on same, gyrus is center for flexion of paw.

7, 11.—Centers for muscles for closure of eye.

8.— " " mouth-retraction and elevation of opposite angle.

9.—Opening movements of mouth and tongue, also *barking.*

11. Retraction of angle of mouth.

12.—Dilation of pupils and wide opening of eye.

13.—Movement of eyeballs to opposite side.

14.—"Pricking up" or sudden retraction of opposite ear.

15.—Torsion of nostril on same side, as from irritation of nostril.

The application of the electrodes to point 21, produced drawing back of the head and opening of the mouth, with a feeble attempt at a cry or growl (the animal being very much exhausted). Repeated applications of the electrodes to this point and its neighborhood, caused whining and growling noises "like those which a dog makes in its sleep and which are supposed to indicate that it is dreaming." The location of a number of other centers in the brain of the Dog is shown in fig. 359. The description accompanying this figure sufficiently explains it. The points made out are only those from which some sort of motor response could be obtained, when the points were stimulated.

We now come to compare these results with those assigned to monkeys and men.

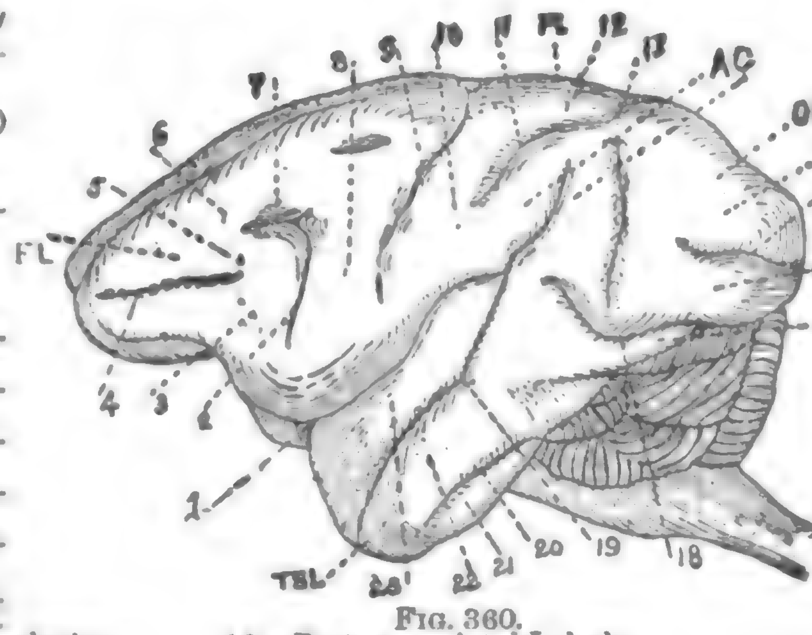


FIG. 360.—*Brain of Monkey (Macaque) showing position of convolutions, &c.* (*Ferrier.*)

1.—Fissure of Sylvius.
9.— " " Rolando.
13.—Parieto Occipital Fissure.
F L.—Frontal Lobe.
P L.—Parietal "
O L.—Occipital "
T S L.—Tempero, Sphenoidal Lobe.
6.—Superior Frontal Convolution.
5.—Middle Frontal Convolution.
3.—Inferior Frontal Convolution.
7.—Superior Frontal Sulcus.
4.—Inferior Frontal Sulcus.
2.—Antero-parietal Sulcus.
8.—Ascending Frontal Convolution.
10.— " Parietal "
11.—Intra-parietal Sulcus.
12.—Postero-parietal Lobule.
A G.—Angular Gyrus.
23, 22, 21.—Superior, Middle and Inferior Tempero-Sphenoidal Convolutions.
19, 20.—Superior and Inferior Tempero-Sphenoidal Sulci.
14, 16, 17.—Superior, Middle and Inferior Occipital Convolutions.
15, 18.—First and Second Occipital Fissures.

FIG. 360.

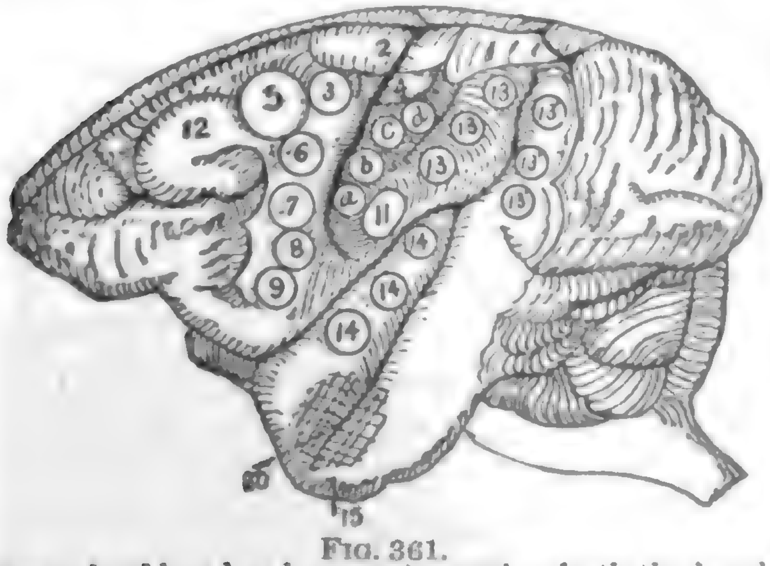


FIG. 361.

FIG. 361.—*Brain of Monkey (Macaque)* showing position of sensory and motor cortical centers.

Explanation for figures 361, 362, 363, 364.

1.—*On Postero Parietal Lobule; Center* for such movements of the leg and foot of the opposite side as are concerned in locomotion.

2, 3, 4.—*On Convolutions bounding the upper extremity of the fissure of Rolando; Centers* for various complex movements of arms and legs, as in climbing, swimming, &c.

5.—*At the posterior end of the superior frontal convolution at its junction with the ascending frontal. Center* for extension forwards of hand and arm as in putting forth the hand to touch something.

6.—*On the ascending frontal just behind the upper end of the posterior extremities of middle frontal convolution. Center* for hand and forearm particularly the biceps muscle in flexion of forearm and the outward wave in supination.

7 and 8.—*Centers* for the elevator and depressor muscles, respectively, of the angle of the mouth.

9 and 10.—*On Brocas Convolution. Center* for lips and tongue in articulation. Its disease causes aphasia. Beneath and a little in front of the figure 9 is the *Island of Reil. Center* of speech.

11.—*Center* for the platysma and risorius muscles in the retraction of the angle of the mouth. (See fig. 66.)

12.—*Center* for lateral movement for head and eyes with elevation of eyelids and dilation of the pupil.

a, b, c, d.—On ascending parietal convolution. Centers for movement of fingers and wrist.

13, 13'.—*On the supra marginal lobule and angular gyrus. Centers* of Vision, which also embrace additional portions of the occipital lobe.

14.—*On superior tempero-sphenoidal convolution. Centers* of Hearing.

15.—(Fig. 361.) *On exterior aspect of Uncinate Gyrus.* Region of Smell. (See fig. 367.)

20.—(Fig. 361.) *Shaded area in temporal lobe in sympathy with region of smell and taste.* Destruction of this region in the monkey causes loss of smell on the same side, and also affects the sense of taste.

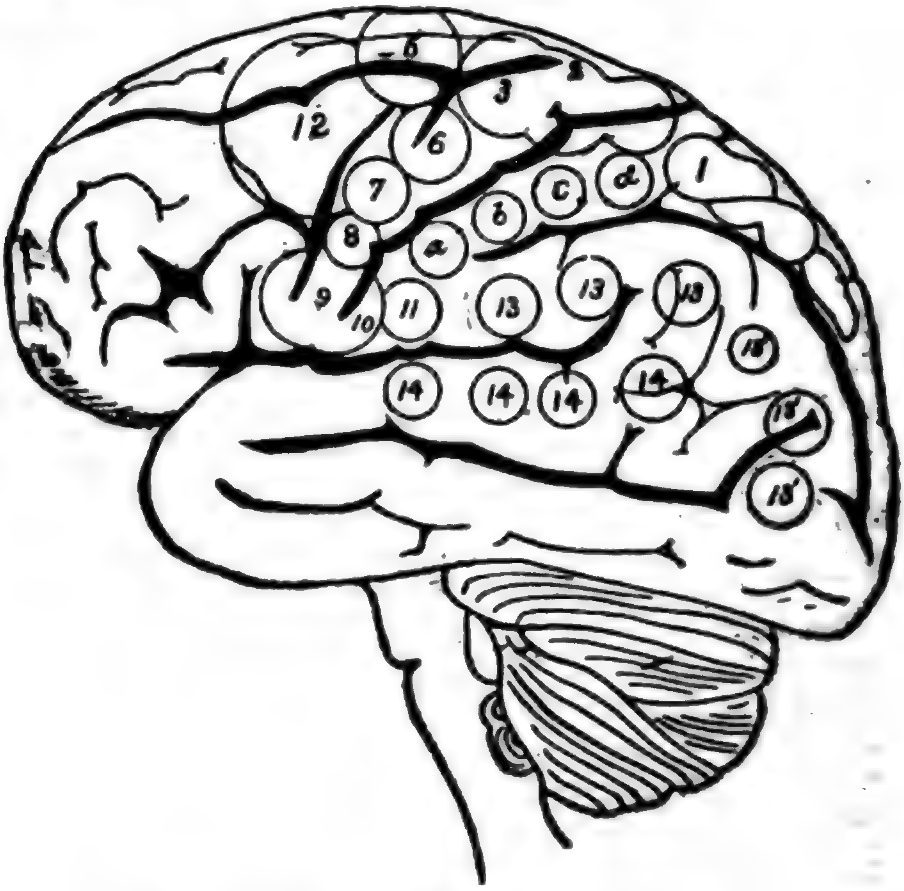


Fig. 362.

Human Brain. (References same as for 361.)

A comparison of the figures and descriptions shows that there is a practical identity between the brains of monkeys and men, as to their sensory and motor functions. The same parts receive impressions from the eye, ear, organs of smell, &c., and identical parts are concerned in despatching the motor stimuli to the various muscular parts. Between these sensory and motor areas of the brain and aside from them are considerable tracts whose office it is to condense and co-ordinate the different sensory stimuli. The more cells there are that are employed in this business, the more consistent, positive and powerful will the resulting motor action be. The absence of such cells would leave the individual subject to each sensory impulse as fast as it came up. Everything would be done without reflection, and the cerebrum without these intermedial condensing and balancing organs, would be such a machine as the spinal cord or the medulla oblongata.

Of the considerable areas, both in the frontal and the posterior lobes,

not accounted for in the foregoing charts of the brain, we must probably assign a part to these intermedial organs formed by the influence of various stimulations acting and reacting upon the cells after they are forwarded inwards from the first receiving sensory cells.

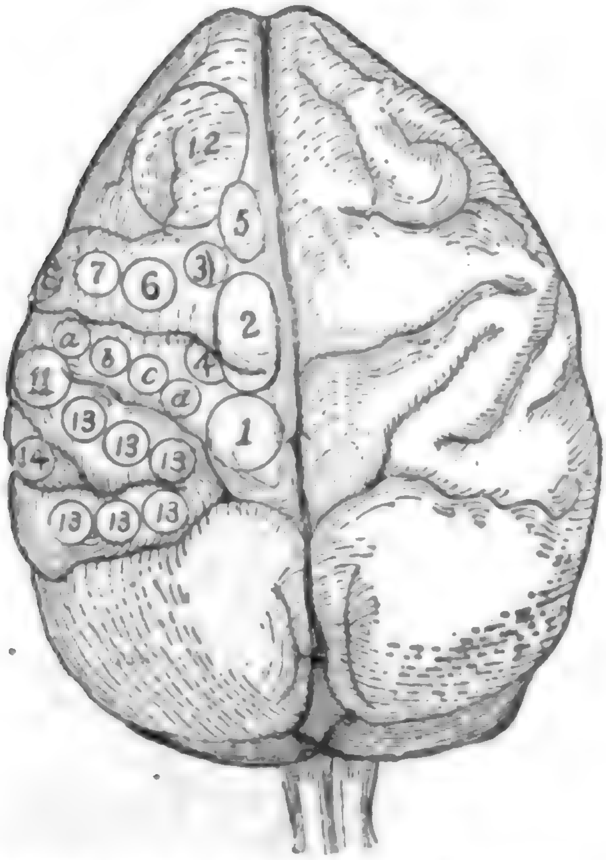


Fig. 363.—Top view of brain of Monkey, Macaque.

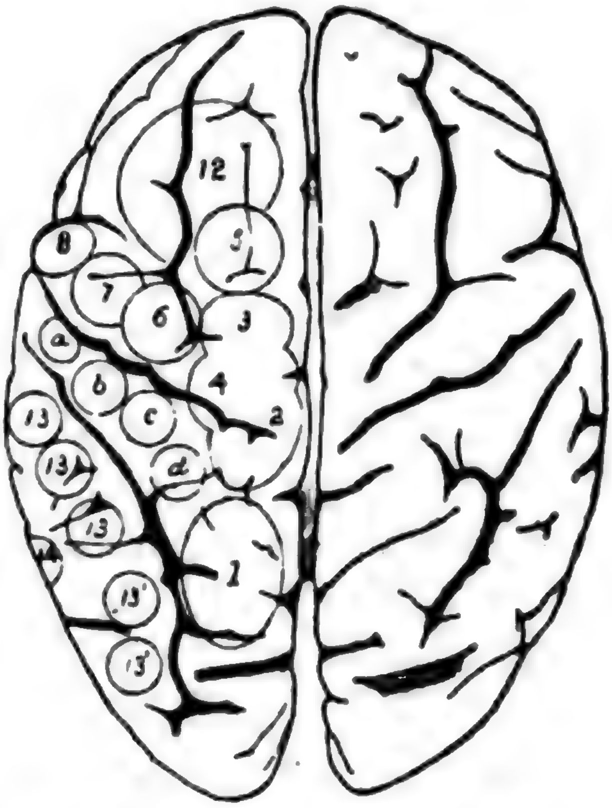


Fig. 364.—Top view of brain of Man.

The large vertical, mesial surfaces of the hemispheres, which are found next to great vertical middle fissure, are found to contain both motor and sensory areas, see figs. 365 and 366. The calcarine fissure,

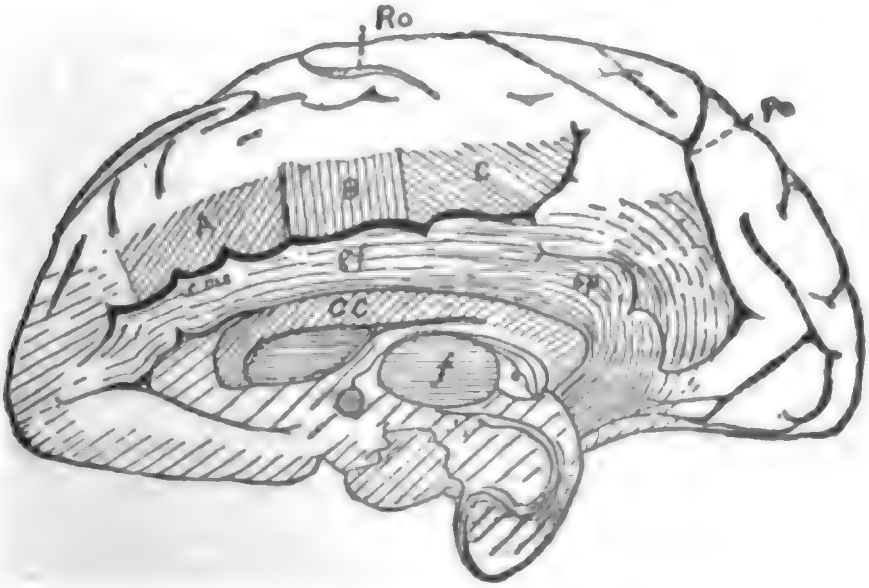


Fig. 365.

Fig. 365.—*Mesial surface of the right Hemisphere of Monkey.*

A.—Motor area, Arm and Head.
B.— " " Trunk.
C.— " " Leg.
CC.—Corpus Callosum.
cms.—Calloso-marginal fissure.
gf.—Gyrus fornicatus.
sp.—Sub-parietal Sulcus.
Po.—Parieto-occipital fissure.
Ro.—Fissure of Rolando.

oc, fig. 366, marks the position, within, of the hippocampus minor in the posterior cornu of the lateral ventricle. In the monkey, the calcarine fissure joins the hippocampal sulcus, but not in man.

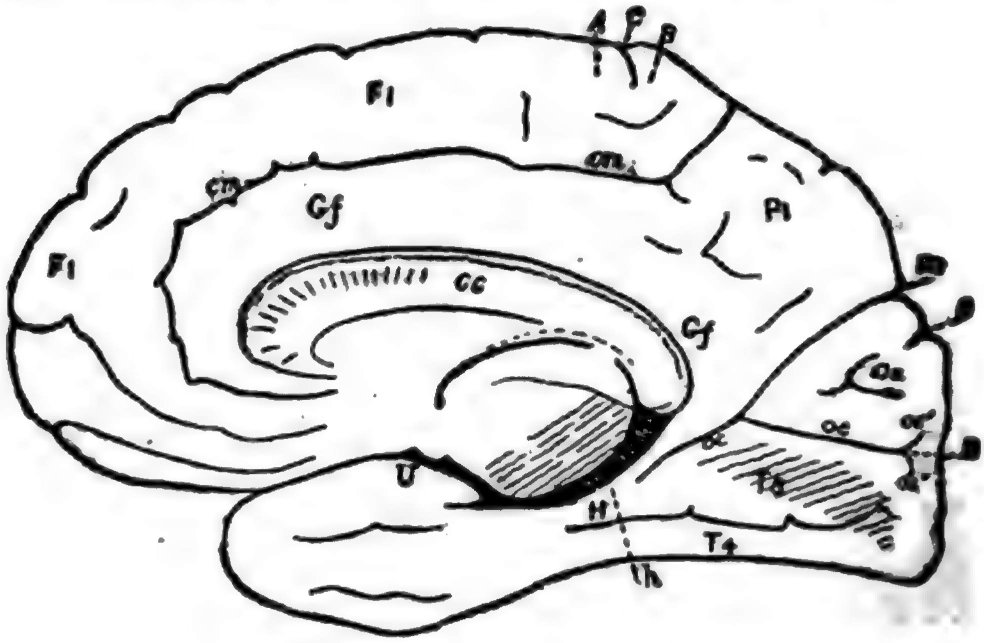


FIG. 366.

FIG. 366.—*Mesial surface Right Hemisphere of Human Brain.*

CC. Corpus Callosum.
Gf. Gyrus Fornicatus
H. Gyrus Hippocampi.
h. Sulcus Hippocampi.
U. Uncinate gyrus.
cm. Sulcus Calloso-marginalis.
F1. Median aspect of the 1st Frontal Convolution.
C. Terminal portion of the fissure of Rolando.
A. Anterior Central Convolution.
B. Posterior " "
oz. Cuneus, or internal occipital lobule.
Pi. Precuneus.
Po. Parieto-occipital fissure.
O. Transverse occipital sulcus.
oc. Calcarine fissure.
oc′. Upper branch of *oc.*
oc″. Lower branch of *oc.*
D. Descending gyrus.
T4. Fusiform Lobule.
T5. Lingual Lobule.
Gf and *H* together constitute the Falciform Lobe of Broca, and they are the *Centers* for *Touch.*
h is also called the Dentate fissure.
U is also called Hippocampal Lobule, or Subiculum Cornu Ammonis. It is the *Center* for *Smell*, and near by, but not well defined, is the *Center* for *Taste.*

(See figs. 270, 367.)

The sensory tract of the internal capsule comprises its posterior one-third or more. Lesions of this part in man or dog have the effect to produce hemianæsthesia, or loss of tactile sensation and the muscular sense, sensation of heat, pressure, &c. (See *x* fig. 349.) The fibres from the outer third of the foot of the crus cerebri diverge from the internal capsule at the base and radiate outwards and downwards toward the hippocampal region. Lesions of this region Ferrier found to impair tactile sensation. The region includes the gyrus fornicatus, hippocampus, hippocampal gyrus and the callosal gyrus. It includes in short the whole of the falciform lobe, the callosal as well as the hippocampal division, all lying on or belonging to the mesial surfaces of the hemispheres. The various centers of the cortex are connected anatomically with definite peripheral organs of sensation and motion, and disorganization of any part of the complete line leads to atrophy of the rest.

"The occipito angular region (13, 13′ fig. 362) is the cortical expansion of the optic tract in the same sense as the retina is its peripheral expansion, and the destruction of either expansion leads to atrophy of the optic nerves." (Ferrier.) The motor parts of the cortex are the cere-

bral expansion of the pyramidal tracts and the destruction of these parts alone leads to the degeneration or atrophy of the pyramidal tracts. Each particular bundle of the pyramidal nerves has its definite corresponding patch of cortical cells and suffers atrophy only when such definite patch is destroyed.

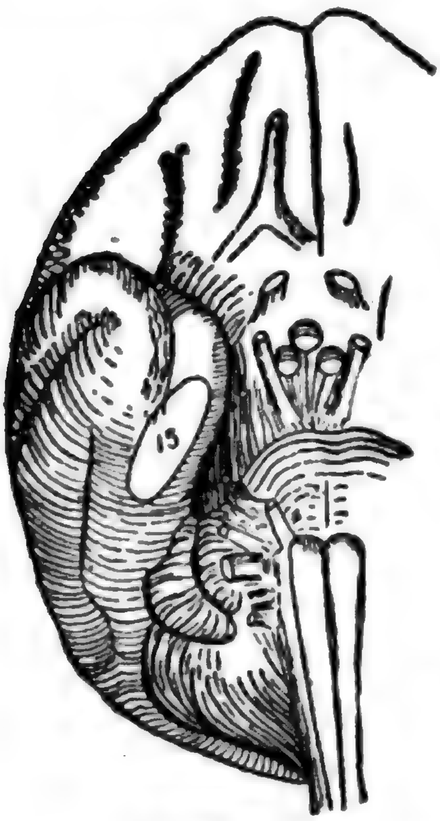


FIG. 367.

FIG. 367.—*Base of right hemisphere of Monkey.*
15.—Anterior and inner aspect of Uncinate Gyrus or Subiculum Cornu Ammonis.
This is the motor area of smell in the torsion of the lip and partial closure of the nostril on same side.

The olfactory tract of nerves coming in from the olfactory lobe divides into two branches, the inner and the outer root (see fig. 270) separated by a triangular space. The inner root joins the mesial aspect of the anterior end of the gyrus fornicatus (fig. 366 *Gf*). The outer root passes outward to the extremity of the tempero sphenoidal lobe where it fuses with the anterior extremity of the gyrus hippocampi (under 15 fig. 367, also *H* fig. 366). In the dog and other acute smelling animals this part of the hemisphere forms a prominent bulb (15 fig. 367) and is called the natiform protuberance, pyriform lobe, or hippocampal lobule. This lobule is the cortical organ of smell for the same side.

Speech. The reference figure 9 in figs. 361 and 362 rests upon a lip or shell of brain substance beneath which is another layer of brain, having in men and monkeys short radiating convolutions called *gyri breves.* This portion of brain is called the Island of Reil. Fig. 350 will help to show its position and fig. 267 its form. This Island of Reil and the patch of brain which overlaps it on the outside are concerned in the motor actions that are involved in the faculty of speech. In this portion of the brain those special combinations of motor stimuli are effected which are essential to the production of articulation. There are other centers from which the muscles of the face or those of the jaws, or of the tongue, of the larynx and of the nose can be worked separately or in partial combination for various purposes, but the nervous combinations necessary for uttering definite articulate sounds are made up in this region.

It is a curious fact in most *right-handed* persons, the Island of Reil on the *left* side only is actively functional, while in *left-handed* persons this part of the right side has been observed in many cases to assume the whole supervision of articulation to the exclusion of the left side.

This patch of brain appears to possess functions of combination in regard to the motor actions concerned in speech, much like those of the cerebellum in relation to the muscular co-ordinations concerned in the common motions of walking, balancing, &c. When *Aphasia* or loss of speech is due to the failure of these centers, the subject loses the faculty of articulation and generally the power of writing his thoughts, although he can still understand the meaning of spoken and perhaps written words. That the disease is due to a loss of the combining power of nervous stimulations and not to the paralysis of the muscles concerned, is proved by the fact that the same muscles are still employed in chewing, swallowing, &c. The cause of the disease is generally due to embolism, or a plugging up of some of the blood vessels supplying this part of the brain. This deprives the part of nourishment and finally causes its softening and destroys its function. The same stoppage is liable to affect other brain centers supplied by the same arterial trunks (of the middle cerebral artery), and so may cause the destruction (in right-handed persons) of the motor centers governing movements of the right hand and face, so that paralysis of those parts is apt to accompany aphasia. After speech has been lost by lesion of the left motor speech center, there are cases on record in which it has been reacquired by the education of the corresponding center on the right side. There is reason to doubt whether the education of the right speech center is entirely avoided as often as the physiologists appear to think. There are many cases of aphasia accompanied by *left* hemiplegia showing that in such cases the motor speech center was on the *right* side and became involved with the centers for muscular motion on that side. It seems probable that in many cases both sides are educated, one perhaps more than the other.

There is another form of aphasia called *Amnesia* (forgetfulness), or sensory aphasia. This arises from lesions of the centers of sight or of hearing. When a certain sight center is impaired, particularly the angular gyrus of the left hemisphere, (see 13, fig. 359; A G, fig. 360; 13, 13′, fig. 362) the person loses the memory of the associated written symbol, which belongs to a particular articulate sound; that is, having the written symbol he cannot translate it into spoken language or tell what it means, although he can understand spoken language, and even write from dictation. In the case of failure of the hearing center, the person cannot understand spoken language or repeat what he *hears*, while still able to articulate what he *sees* written. The auditory center is the "superior tempero-sphenoidal convolution." (14, fig. 362.) What is lost in sensory aphasia is not general vision or hearing, but the association between these senses and articulate sounds and written symbols, respectively. So it does not necessarily follow in all cases of amnesia,

that the sight or hearing centers themselves are affected, but the trouble may be in the connections between these centers and the motor centers in the speech area. For the motor stimuli are the results of preliminary sensory stimuli, the latter directly or indirectly giving rise to the former. The motor action of articulation will therefore fail if the sensory stimuli are cut off from the co-ordinating speech organ.

Ferrier is of opinion that whatever may be the case with the invertebrates, *Consciousness* in the vertebrates, including man, depends upon the cerebral hemispheres. According to his view, the mesencephalon, the ganglia between the cerebral hemispheres and the medulla oblongata, is subject to impressions from the environment, and to resulting co-ordinated movements without conscious sensation; is, in fact, a complete reflex unconscious machine. The term *sensory*, which is so constantly used with reference to the afferent nerves and ganglions, must be understood to imply only that which is *afferent*, and not as committing ourselves to the idea that their activity necessarily involves consciousness.

A lower vertebrate, reptile, fish or bird, deprived of his hemispheres, but possessing the sensory organs, will perform all actions, even well co-ordinated ones in obedience to external stimuli, in a purely reflex manner, the element of memory (and therefore of consciousness, according to Ferrier) not entering into the composition of the action, or modifying it at all. A bird thus mutilated can stand, and recover its equilibrium when pushed over. If placed on its back it can get up on its feet again; if thrown into the air it will fly. If a fly alight on its head it will shake it off. If ammonia be held near its nostrils it will start back. It usually seems asleep, but can be roused, when it will open its eyes and look up. Sometimes it rouses up, yawns, shakes itself, dresses its feathers with its beak, moves a little, stops, and stands first on one foot, then the other. It will not take food, and resists being fed, but when the food is once in the mouth it is swallowed. Fed artificially it may live for months, but would never eat if left to itself. Ferrier says, "it is and remains unconscious, and void of sensation."

If a fish be deprived of its cerebral hemispheres, it continues to move in the water as well as ever. It preserves its equilibrium, swimming straight forward, but turning out to avoid objects placed in its path. Nevertheless the fish is insane, for it no longer perceives food, or attempts to feed itself, and would starve in the midst of plenty. It is under an irresistible impulse to go, and it keeps on till physically exhausted, or restrained from without. It acts like the frog deprived of its hemispheres, that is, it is subject to the direct impulses of the stimulations of the environment through contact. The resistance of the water affords the stimulation necessary to excite action in the muscles of tail and fins and cause it to move. If food were put into its mouth

it would be swallowed and digested, but in order to make an effort to *take* food to put into the mouth, there must be a *memory* of the relationship between the food and the feeling of satisfaction which follows the eating of it, which memory belongs to the missing hemispheres. In other words, the track for the stimulations from food not in actual contact with the organs of deglutition to the motor nerves concerned in appropriating it, is through the cerebrum. The food is doubtless *seen*, but it is seen as an obstruction to be avoided, if in the way, or, if out of the way, as having no relationship whatever to the fish. The sense of smell is not operative, as the olfactory lobe has direct connections only with the hemispheres, and this sense is largely concerned in the fish's quest of food. And here we may again insist upon the homogeneousness existing between the habits upon which are founded the functions called reflex and those called purposive. In an unmutilated fish a stimulation going from an object, which may be either an obstruction or an article of food, passes to the eye and optic lobes. It is divided, the first part going directly to the medulla oblongata, and thence on to certain muscles and limbs, which are moved in such a manner as to steer the fish away from the body as from an obstruction; the second part goes to the medulla oblongata by way of the cerebral hemispheres, and passes on to the very same muscles and limbs, and may steer the fish *toward* the body as to an article of food. Now, when the fish is deprived of its hemispheres, the influence of the second part of the stimulation is annulled, while that of the first part remains in full force and effect. In the second case, we are accustomed to say the fish is governed by a perception of the presence of food. Why have we not as good reason in the first case to say it is governed by a perception of the presence of an obstruction? Yet it is demonstrated that the perception of the obstruction lies, or may lie, exclusively in the optic lobes and the medulla oblongata; and it becomes obvious that while there are two separate machines for these two perceptions, the only difference between them is that the one which perceives that the object is *food* is somewhat more complicated than the one which only perceives that it is an obstruction.

Dr. Ferrier's experiments prove that the action of the cerebrum is reflex in the same sense as is the action of the spinal cord, medulla oblongata, cerebellum, optic lobes and corpora striata. Actions which are always recognized as prompted by ideas and emotions, and are the usual "expressions" of these so-called "mental states," are performed in utter unconsciousness, and in the absence of any *mental* state, as such term is usually understood. The process is exclusively physical; a form of physical energy communicated to the physical organs which constitute the cortex of the cerebrum, produce physical demonstrations.

These demonstrations, we have been in the habit of saying, indicate states of the mind, but it is obvious this does not follow. They indicate physical states, and physical states alone are demonstrably sufficient to produce the phenomena which we are in the habit of calling mental.

Animals from which the cerebrum has been taken, may still exhibit, when subjected to the proper stimulations, all the expressions of emotion which would be due to follow these if the animal had its cerebral hemispheres and its consciousness. "They start at sounds, flinch at light thrown in their eyes, or even direct their movements in relation with retinal impressions; respond by movements expressive of disgust or discomfort at unpleasant nasal or gustatory stimuli, and make the most varied reactions to stimulation of the nerves of common sensation. Frogs croak as if from pleasure when their backs are gently stroked, and rabbits scream piteously, and exhibit the various signs of agitation characteristic of intense pain, if their toes are pinched or any sensory nerve severely stimulated." (*Ferrier.*) Nevertheless there is obviously no pain, feeling or consciousness whatever. These same expressions, when they happen during conditions of consciousness, are still reflex, and are performed without the co-operation of the will, and often in spite of it.

"The phenomena observed in animals deprived of their cerebral hemispheres, are in all respects analogous to those observed in human beings under the influence of chloroform. Chloroform, as proved by actual experiment, first annihilates the excitability of the hemispheres, a condition coinciding with the abolition of consciousness, but the mesencephalic and lower centers retain their excitability long after this point has been reached. Hence, impressions, which, under normal conditions would excite pain as well as groans, cries, and the other physical expressions of pain, now merely excite the physical manifestations without any painful sensation proper." (*Ferrier.*)

This is important as showing beyond controversy that the centers governing physical demonstrations of emotion, are set going by stimulations coming direct from the environment through the nerves of sensation, without the co-operation of the will and without involving the cerebral organs or consciousness in any way. But we know that these very same demonstrations of emotion, through the same centers and reaching the same muscles by way of the same efferent nerves, are also set in motion by stimuli which do originate immediately in the cerebrum among the organs of the internal senses. We are bound to conclude first, that the stimulation which comes from the cerebral centers is of the same nature as that which comes from the peripheral senses, and we are confirmed in the position that the cerebral or internal senses are only elaborated forms of the peripheral senses, and the stimulations pro-

ceeding from them are only reverberations of peripheral stimuli; and second, that since these phenomena are thus shown to be of the same essential nature, and since one set, namely, those manifested through the medulla oblongata and optic lobes alone, are purely automatic, it follows that the other set in which the cerebrum is also involved, are likewise purely automatic. (This subject will be taken up again.)

What we call the *Will* arises from action taking place in the cerebrum, and is therefore to be classed as a function of the cerebrum. Its nature is discussed in a separate chapter. In man and the monkey, destruction of the motor areas of the cortex of the cerebrum produce complete paralysis, and nothing can be added to this by the destruction of the corpus striatum. In the case of the dog the destruction of the cortical motor areas causes only partial paralysis, but if the corpus striatum and motor part of internal capsule be also destroyed the paralysis is complete, (at least for a time,) and the dog lies entirely powerless and helpless. In the case of the rabbit, destruction of neither the cortex nor the corpus striatum nor of both are able to abolish the animal's power of balancing or locomotion.

These facts go to show that in Man and Monkey the cerebrum has superseded the lower centers of sensation and motion to a larger extent than in the Dog, Rabbit, &c. That is, the motor actions of man performed now are stimulated by the sensory agitations, not only of to-day, but by those of yesterday, of last week, of last year, or even of last century; the sensory impressions of such agitations remaining in the cerebrum in a condition to produce memories. In the dog the cerebrum is relatively smaller, and so, fewer of his actions are due to former sensations and more to present ones, the latter doing their work largely through the lower centers, while the former do theirs chiefly, if not exclusively, through the cerebrum.

CHAPTER LXIV.

MEMORY.

It was pointed out in chapter 62 that the general cranio-spinal nervous and ganglionic system divides into five separate subdivisions, each of which may be operated in some degree of independence from the others. The first of these is the Spinal Cord, the stimulation of which from external sources, when not interfered with by the other ganglionic centers, overflows at once to motor nerves and causes a muscle contraction. This sort of action is called *Reflex*. Next is the Medulla Oblongata. The motor action here arises from stimuli received from more varied sources, and it affects not only external muscles, but glands, the

visceral muscles, the circulatory system, &c. The action is more or less indirect, and made up by the combination of several stimuli. It may be called *Excito Motor.* Third is the *Cerebellum*, the balancing and co-ordinating action of which has been called *Automatic.* Fourth is the machine made up of the *Basal Ganglia*—the optic lobes, thalamus, striatum, &c. The stimuli operating this machine are chiefly derived through the senses, not only touch, which is chiefly concerned in the reflex actions of the cord, but sight, smell, taste and hearing as well. This action is therefore denominated *Sensori-Motor.* Fifth is the cerebrum. The motor actions starting here arise from stimuli which depend primarily on the senses as much as those of the centers below. But the cerebrum is pre-eminently an organ of memory, and the sensory stimuli become cumulative, their effects often lasting for many years. These memories, and the new conceits that are formed out of them, constitute our *ideas*, and they become largely concerned, with or without the present or immediate sensory impressions, in forming the motor stimuli of the cerebrum, from which circumstance these stimuli are called *Ideo-Motor.*

While these terms are convenient for purposes of study, we must bear in mind that they do not indicate any radical or essential difference of principle in the classes of action they describe. *All* the stimuli are sensory to begin with. The lower ganglia are influenced by but few of the senses, the cord by only one or two. The higher ganglia are moved by all the senses. The basal ganglia depend for their stimulations chiefly on the sensory impressions of the moment, a very small proportion being derived from the memory of past ones. The impulses sent from the cerebrum may be made chiefly from the memories of past sensory impressions. Thus, all these machines depend on the same motive stimulation of external forms of force by way of the sense organs, and the difference in their actions depends on their susceptibility to be set in motion by a larger or smaller number of these sensory forces.

At birth, every cell of the brain is connected by nerve fibres with some certain sense organ. We have seen that the different sense organs each have their definite patches of brain, and the practical constancy and uniformity among the higher mammals and men of these connections, prove them to be hereditary through a very long line of ancestry, antedating the human race.

The arms, legs, fingers, &c., of a new-born infant are in a very incomplete condition so far as use is concerned. They have not the power to perform a vast number of movements which they afterwards get the ability to do. But this awkwardness of the limbs is shared by a corresponding awkwardness of the cells in the spinal cord and brain. In fact, the cells and the limbs together constitute a single machine, and

neither set would ever be or become operative without the other. A few muscular movements are performed at birth, and even before, but the greater part, even of reflex movements, have to be acquired by experience; that is, under stimulation from external sources of energy, by way of the organs of sense.

If you touch the naked foot of a sleeping child gently with a feather, the limb will probably be withdrawn, perhaps without waking the child. The stimulus has formed a nerve current, which has gone up to the ganglions in the spinal cord, and has been deflected thence back to the muscles of the same limb, and their contraction withdraws it. But although this action is performed in unconsciousness and without involving the cerebral cells at all, it must nevertheless be learned. For if the experiment be performed upon a *very young* infant the foot will not be withdrawn, and if the irritation be persisted in, the result will be simply pain or uneasiness, indicated by its crying. The crying is reflex, indeed, but it arises from a reflection from the medulla oblongata instead of the spinal cord. This reflex action of crying, like that of sucking, does not have to be learned. These were so thoroughly practiced by the infinite line of our ancestry that through habit and heredity the parts involved in these reactions are perfect at birth, and begin to operate as soon as the proper external stimuli are applied. But the muscle movements of the limbs, even those which are reflex, and much more those which are purposive, must be acquired, although the hereditary machinery is so nearly complete at birth that it is soon made operative by a little practice; or, as we might say, a little *more* practice, since whatever approach to perfection it has, results from ancient practice. It is only after repeated applications of the stimulus to the skin of the new baby, that the current is able to make its way entirely around the circuit. The conducting line, consisting of the afferent nerve, the cells of the ganglion, and the efferent nerve, offers resistance probably in all parts, and certainly in the cells. But this conductor is composed of plastic materials which yield more or less at every assault of the polar current, and finally become its facile pathway. It is obvious that every attack of the stimulating current upon the cells, differentiates them more and more, and is able to penetrate further, and affect a greater number of them. Further habit makes them more easily moved, so that a constantly decreasing proportion of the stimulation is required to move the cells, and a correspondingly increasing amount of it is transmitted down the efferent nerve, increasing the force of muscle excitement and contraction. Thus, the difference between an inexperienced and a differentiated cell is, that the latter is readily moved by the nervous stimulation, while the former is not. This difference constitutes the physiology of *memory*. While the cell remains readily movable, it has *memory*.

When, from disuse, it is no longer excitable, it has *forgotten.* Its excitement while under stimulation is called its *erection*, or *erethism*, and is, in fact, its *remembrance.*

If the foregoing definitions are correct, and we shall have further proofs that they are, there is no difference in principle between the memories and recollections of the reflex centers and those called excito-motor, automatic, sensori-motor or ideo-motor. We are apt to associate remembrance with consciousness; but we shall see further on that at least, remembrance is not in any way founded upon consciousness. Since consciousness, or at least the most important consciousness, appears to arise in the ideo-motor centers in the cerebrum, the habit of associating it with remembrance leads to an ill defined inference that the latter is a function of the cerebrum alone. But as there is no necessary connection between the two, the inference is entirely unfounded, and is, in fact, false. The difference between the remembrance of the spinal cord and that of the cerebrum, is one of degree and detail, not principle. In all cases it consists in the re-erection of cells which have been erected by a previous stimulation. In the case of the spinal reflex cells, there is only one sort of stimulation which will produce their re-erection, and that is the same external sensory touch impression that differentiated and erected them in the first place; and the quantity or quality of their memory is measured by the superior ease and facility with which they yield to the stimulation now, as compared with their inertia and reluctance when agitated the first time.

The memory of the cerebral cells is of precisely the same nature as that of the spinal cells. But the cerebral cells have connections in all directions with each other, and they are stimulated through these connections from many original sources, although before a cell is re-erected the stimulation doubtless takes the same form that was necessary to erect it in the first place. At any rate, an ideo-motor cell may be re-stimulated by an associated cell, of which there may be many, as well as by a new sensory impression from the environment; while the spinal reflex cell is restimulated only by the external sensory impression. Not only are the memories of cerebral sensory cells liable to be aroused by the action of associated cells, but the motor action, to which such stimulation might lead, is equally liable to become, by the same sort of interference, stronger or weaker, and to be diverted or deflected, and take a route not taken before. The motor action of the spinal reflex cell is little liable to any such accidents. As the revival of its memory is effected by a uniform sensory stimulus, so there is a sameness in the resulting motor action.

The view of memory given here makes it necessary to distinguish between conscious and unconscious memories. Commonly, only the for-

mer is recognized, so that the terms remembrance, recollection, &c., are taken to signify states of consciousness. I have used the word *remembrance*, above, to signify the renewal of a former activity of cells, regardless of whether such activity is followed by consciousness of it or not. To avoid coining a new word, *recollection* may be used to signify an activity of memory of which we are conscious. By this use, a recollection is the (conscious) sensation of a remembrance. To illustrate: light is a sensation of sight; recollection is a renewal of the same sensation in reduced intensity. Both are states of consciousness, but neither of them is essentially a cause or a necessary link in brain differentiation or restimulation. When they occur they are effects, light arising from sensory *impression*, and recollection from *remembrance*, or cell restimulation, occurring when such impression or remembrance reaches a certain degree of intensity.

The cerebral cells, whose remembrance is liable to overflow to other cells and restimulate them, are called organs of the *internal senses*, their relationship to the other cells being similar to that of external organs of sense. If, when a cerebral act is performed or suffered it is not done consciously, it is not remembered, probably because an intensity of action strong enough to differentiate and stamp a character upon the cell is also sufficient to arouse sensation, while if it cannot arouse sensation it is not strong enough to differentiate the cell. There are many partial differentiations caused by faint sensory impressions, that are without permanent effect, the cell relapsing to its former state. No memory follows these impressions, and yet a large number of actions are performed under them, especially those which are habitual. Thus, a man in the habit of winding his watch at a certain hour, will finally come to do so almost unconsciously, so that an hour later he will be unable to say whether he has wound it or not, and will try to do it again. Thus, the same impression made in a state of *inattention*, or reduced consciousness, is not sufficient to make a permanent alteration in the cell so as to establish a memory, nor does it arouse a full-grown sensation of itself. But we must remember that the state of attention is altogether due to the (relative) *force of the impression.* If the stimulus remains uniform, as in the above example, it comes to have relatively less and less power to arouse attention and sensation, because, as we shall see, sensation follows, and is due to the *friction* of the resistance of the nerves and cells against the current energy; the amount of the friction indicates the *wear* and *tear*, and that determines the amount of blood supplied to repair the cells, and *attention* is simply our sensation of the increase of the blood supply. Long repeated habit reduces the friction; and the reduction of the sensation of the *impression*, of wear and tear, of blood supply, and of attention, immediately follow. At the same

time the habit which tends to constantly reduce the keenness of the sensation arising from a habitual stimulus, tends also to increase the ease and rapidity with which the stimulus is followed by motor action, so that under the force of habit, actions tend to become *unconsciously* automatic. The increase of this tendency, with its hereditary transmission, intensifies *automatism* into *instinct*. This process thus tends to reduce the memory function of the cerebral cells, while it builds up that of the ganglions in the lower brain centers and the spinal cord. The more exactly each repetition of an automatic or instinctive action copies the previous ones, the less of consciousness goes with the action, and the slighter the memory of it that remains. The sameness of the muscle movements in walking, have rendered them so far automatic in adults, that on a smooth road a man may walk miles in unconsciousness of the steps he takes.

The cell organs in the cerebrum, like those in the lower centers, are liable to become so drilled by habit that their action becomes practically frictionless, and they are therefore stimulated without arousing consciousness. A large proportion of our mental action goes on thus unconsciously, not counting that which makes up the motor stimuli of the unconscious muscular movements. In this action, the cells which are connected with each other directly or indirectly throughout the brain, constantly influence and stimulate each other; that is, when one is excited, those in certain relationship with it share the excitement. When the excitement is stronger, it extends also to others less intimately related, and so on.

The effect of the ramifications and intersections of memory tracks in the cerebrum, is seen on many occasions. There are persons who when they attempt to sing some particular air are liable, in the midst of it, to switch off upon another tune. This happens when both airs are written in the same time and meter, and have a strain common to both in the same relative part of the piece. When this common strain is reached, the unguarded singer (when singing by ear) is turned off, and winds up on another air than that with which he commenced. Example: "Capt. Jinks" and "The King of the Cannibal Islands."

It is curious to observe how the conversation of a company drifts about from one subject to another, one thing "calling up" another ad infinitum. The relationships of the subjects by which they thus call each other up, are often apparently of the most irrelevant kind. The weather we have here to-day reminds one of similar weather he experienced once in Palestine or Mexico, and the thought transported to Mexico, is suddenly changed from the weather to something else seen in Mexico, a burro* perhaps. The sound of the name recalls to another

* A diminutive donkey; pronounced the same as bureau.

the circumstance of having seen such a beautiful French bureau in New York, which suggests to another the question, why such an article should be imported instead of being made at home, which question opens up the tariff policy of the country, which leads to the discussion of the general politics of this country, then to that of Europe, and so on without end.

Our waking ideas are of about the same consistency and continuity. They are changing constantly, like a series of dissolving views. Even when some strong motive is holding us to a particular and persistent line of thought, images foreign to the purpose are constantly being revived and interposed. The stimulus which ought to be expended in arousing apt and correlative images or recollections, is frittered away upon diverging tracks, which never return to assist in the formation of the purposive idea.

The prattle of children is also of this wandering and flighty nature. But it is stimulated largely by sensations directly from without, instead of those stored sensations in the internal sense organs of the cerebrum. But the effect being much the same, the fact affords both a proof and an illustration of the reality and the function of the internal senses. The first stimulations which assail us in infancy are manifestly the external stimulations which reach our sensory cells through the external sense organs. The process of storing these sensations in the cerebral cells, continues during life, and in the revival of them, which constitutes recollection, consists the phenomenon of internal sensation, the cerebral cells being the internal sense organs. In old age, and as life progresses, particularly with people of recluse and retired habits, more and more of the sensations which govern their actions and form the basis of the new images composed in their brains, are furnished by these internal senses. The observation of the external senses becomes less acute, and they exert less influence.

The erratic nature of dreams is likewise due largely to this same entanglement of the lines of memory. At any rate, this is certainly true of all dreams that have any coherency or continuity, as many of them have. Such dreams are much like the ordinary waking movements of the brain, frequently changing the subject, and gliding from one image to another, but yet preserving in each image its proper and rational features. But there are dreams in which the images are all broken up, and the parts thrown together in the utmost jumble and incongruous confusion. The head grows out of the back, feathers grow from the toes, people walk without feet on the water, sail on the land in boats, fly without wings, are chopped to pieces by impossible dragons, without injury or pain. These things all appear to happen without in the least exciting surprise or any suspicion of incongruity.

At the moment of the waking of some of the cells, others are still in the insensibility of sleep. Those first stimulated and erected may lie along a continuous and coherent track of memory, arousing the whole line, and giving a sensation of a complete memory, which, mingling with other such lines, produce an image more or less complete. But in most lines of memory, some of the details are faint, while others are deep-set. If two persons undertake to relate the same incident, one will reproduce details not remembered, or remembered faintly, by the other. So, in the re-erections of cells at the moment of waking, we can readily conceive that before the action of the stimulus has reached its maximum, these faintly impressed cells may be passed by without being aroused, the result being a confused lot of incomplete images jumbled together without order or coherence.

In the semi-conscious state in which dreams take place, those cells on which depend the standards of rational deductions and the moral sentiments, are usually still inactive and asleep. It is on this account that neither the intellectual faculties are surprised, nor the moral sensibilities shocked, by our dreams, as they would be often by such images if presented in waking hours. The cells in question belong to a class whose excitation has not been, in the first place, directly from the environment, but at second or third hand from the cells of sensory impression. It is their re-erection in sleep that constitutes what is called unconscious cerebration. The only distinction between that and dreaming, consists in the class of cells restimulated, and the completeness and coherence of the recollection.

Injury to the cerebrum deranges or destroys the memory, affecting it in many different ways. Sometimes epilepsy or apoplexy destroys the power of the reception of *new* impressions, so that the patient does not remember anything that passes from day to day, whilst very old impressions come up vividly. At other times, the old events are blotted out, and the late ones are vivid.

We are accustomed to talk loosely about the revival of a remembrance through the will. Using the term as commonly applied, we yet find the process is not by any means a direct and simple one. We do not call up any idea by simply *willing* it, for this presupposes that we have an idea of the idea we wish to recall, which if we had, no further recollection would be necessary. What is really done in recollecting is the fixing of attention upon such outlying contiguous and associated or constituent elements of the idea we want as *are* present in the memory, so that the activities of these will overflow along the lines of association by which they were connected in the first place with the ones now wanted, and so re-erect them, or reproduce them by *suggestion.* Thus, in trying to remember a quotation, as, for example, a verse of poetry,

when we come to a gap in the memory of a word or a line, we go back to the beginning, and recite again as far as we can, instinctively expecting that what we do know will re-arouse that which has escaped us. It is the same in a passage of music, in a tale, in a landscape, in a business transaction, &c.

The process of suggestion is being constantly enacted automatically, and ideas are incessantly arousing others with which they are connected. It is upon the intrusion of an active stimulus from the environment that this automatic "train of thought" is disturbed, and *attention* is concentrated upon some particular idea and its correlatives. In such case, the external stimulus is itself the first term of a new series of suggestions, which follow each other till the idea required is found, the reaction from which extinguishes the first term and neutralizes the stimulus. It is evident that the new train of stimulating suggestions is as automatic as the first, the only difference being the immediate origin of the initial stimulus. Upon first waking in the morning, cerebral activity begins in a helter skelter sort of fashion, the heat of the circulation alone (probably) furnishing by its frictional arrest in the vascular tubes the necessary nervous current to stimulate those cells which happen to be the most mobile and susceptible. This mobility and susceptibility depend directly upon the habit of the cells, and inversely upon their fatigue, exhaustion, &c. The effect of the new incoming stimulus, which gives a fixed direction to the flow of ideas, is produced by the flow of this stimulus over the track which has been taken by similar stimuli in the past, and the re-erection of some of the cells which were affected by the former stimulus. This process determines the flow of blood to the spot stimulated, and arouses that degree of sensation we designate as attention. Observe that attention is not the process, nor the cause of it, but only an effect in sensation of the stimulation which causes the increased movement of the blood, and probably of the movement itself.

The general position of the tracts of the cortex devoted to the different senses, was pointed out in the last chapter. These tracts are hereditary, and at birth are of a more or less definite extent and limit. If, in a young dog, the area in connection with the eyes be cut out, the animal will never have any conscious impression of things seen, and no sight memories. According to Munk, the first sensations (of sight) in the young animal differentiate the cells in the middle of the area; so that, if, after the dog has had some experience, the central part of the sight area be cut out, the memories of the things he has seen will be totally destroyed, and irrecoverable. But the dog will not be blind, he can begin over again, and his sight differentiations will go on as before, in the margin of cells still left in the sight area, and he may acquire a respectable stock of new sight memories (but, of course, never recover

the old ones). Until he does this, he does not *know* the things he sees, although he might have been familiar with them before his mutilation. He has to learn anew what a gun is, and what birds are, and how the latter may be affected by the former. He will have to learn distances, because at first all things will appear to be immediately in contact with his eyes.

If *all* the sight area in the cortex be destroyed, the dog will still not be sightless, but he will not remember anything he sees, and never be able to acquire a conscious sight memory. His sense of sight will be good only while his eyes are fixed upon an object, such as an obstruction in his path, and the influence of the stimulation will pass into such motor, reflex or automatic muscular combinations as will cause him to avoid the obstruction. But the moment his eyes are off from the object, it will be forgotten.

In the above action of the lower ganglionic centers, we are bound to recognize the unconscious memory function which they possess. The avoidance of an obstruction implies a habit of previous avoidance, and such an adjustment of the machinery concerned, that when the stimulus is applied at the initial point, each part is successively brought into action by the stimulus as it may have been modified and transmitted by the part going before. The peculiar constitution of the machine, which insures the repetition of its former action when it is restimulated, is its memory. In short, its *memory* does not differ from that of a dynamo, or a threshing machine. It is a better memory than that of the cerebrum which arouses consciousness, because the parts concerned are fewer in number, more definitely and exclusively fitted to each other, and of less delicate adjustments. The organs of the cerebrum show the reverse state of facts; the parts related to each other are vastly numerous, and connected in a vast number of ways, with great delicacy of adjustment. This makes it difficult, if not impossible, to ever reproduce a former action of cerebral organs, with precision. In fact, almost every restimulation of the cerebral machine, alters it more or less, which alone insures a change in its memory. Thus, the most accurate cerebral memories are unreliable, and every time the machine is started, it is liable to run in a more or less different manner. The essential features of memory are the same in the lower brain centers and the cerebrum. The element of consciousness, which appears in connection with it in the cerebrum, does not contribute to the perfection of its action; on the contrary, it is an indication of its imperfection, because friction is a measure of force lost in the operation of an imperfect machine, and it is also a measure of consciousness.

As before observed, the inference that the principal cortical organs are located in man in the same parts of the brain as in the higher mam-

mals, is confirmed by the effects of lesions and diseases of these organs. Many cases have been observed in which diseases of vision were found to be due to lesions of the occipital lobe. A common cause of a partial loss of memory is embolism, or thrombosis. That is, an obstruction, usually in the form of a coagulated clot, stops up a small artery in the brain, thus cutting off the blood supply of all the cells which lie beyond the obstruction, and which depend on that supply for materials to repair the waste caused by the work done through them. The arteries divide and subdivide as they pass outward from the great aorta, like the branches of a tree, so that a clot which readily passes along the larger branches will finally reach a twig too small for it to squeeze through. The brain cells beyond the obstruction will at once become functionless, and all the memories depending on their re-erection will be lost until the obstruction be removed. The larger the arterial twig is which is stopped up, the larger is the tract of injured memories; thus a plug at (*a*) will result in greater mischief than if it should get on to (*b*). Abcess, ecpiesma or fracture with compression of the brain, effusion, &c., are attended by injury to some of the sensory or motor memories. A sudden blow upon the head may produce momentary compression of the brain, with sudden and temporary loss of all memory.

FIG. 368.

As mentioned in last chapter, the motor speech memories are located in the Island of Reil. This is smooth in most animals, but in man and the apes it is convoluted, and also to some extent in the porpoise. (See fig. 267.) The principal organs concerned in speech, are single and median, which may perhaps account for the fact that they are usually operated by the speech organ of one side only. In right-handed persons that is the left side, and in left-handed persons usually the right side. The faculty of ordinary speech involves, first, the memory of words; that is, the conception of sounds as pictured in the memory, and their perception as associated with definite ideas; and, second, the memory of the necessary movement of the muscles in the articulation. The first part belongs to the department of hearing. The second, or motor part of the faculty has its seat in the insula, or Isle of Reil. Both parts receive their blood supply and nourishment from the middle cerebral artery, so that injury to this is liable to effect the memory of language, or its articulation, or both. In reading, the sight memories are involved. The reader must have memories in his sight tract in the posterior lobe, of the shapes and appearance of printed words in association with the faculty of the muscular movements necessary to their articulation. The hearing memories may be atrophied, and yet the person be able to read from a book, as deaf persons can often do. In writ-

ing, still another association of memories is required; namely, those in the sight tract relating to the shapes of the letters and words, and those in the motor tract for the arm and hand. (See fig. 362.) So that a person might be deprived of the use of the Isle of Reil and the lower temporal region, that is, he might be both deaf to the meaning of sounded words, and dumb to their articulation, and yet be able to write.

We are likewise to understand that these general memory tracts are cut up into subdivisions, each of which relates to a specialized subdivision of the general function of the tract. Thus, in the motor memories relating to the arm, are included the memories of many thousand special combinations of movement, which, on the whole, constitute its skill and dexterity. If one little cell in this tract should be deprived of its due nourishment, the memories of the motions, of which the function of this cell forms a part, and which may be numerous, would everyone become distorted and incorrect, or totally abolished as coherent motor elements. But we are to remember that it is only the memory of past or habitual movement that is lost. We still possess the ability to learn the movement over again, provided there are other healthy unengaged cells in the tract, and provided there is external motive for the repetition of the several actions which differentiate the cell in the first place.

The following cases I take from Dr. Allen Star's article in the *Popular Science Monthly* for September, 1884: A man was brought into Bellevue hospital in New York, suffering from fever, headache, delirium and stupor, which had developed after a blow upon the head. In addition to these symptoms, he had a paralysis of the muscles on the back of the fore-arm, so that he could not raise his left hand. The general symptoms indicated the presence of an abscess in the brain. To the surgeon familiar with the anatomy, and with the physiological experiments upon animals, the paralysis of the arm muscles indicated that the abscess was situated in that part of the brain whose function it was to raise the hand. He therefore sawed through the skull, over the supposed site of the abscess, and although the hole which he made was only large enough to admit his little finger, the abscess was found lying just beneath it, and was emptied.

The following case happened in France: An intelligent gentleman, while playing billiards, suddenly became aware of the fact that he could see but one-half of the ball at which he was aiming. He had become blind in the right half of both eyes. Soon after, on attempting to read, he found, much to his surprise, that he could not read. He could see the letters and words, but they conveyed no meaning to his mind, and appeared to him as so many forms, just as a set of Chinese letters do to us. He had lost the power to recognize written and printed language.

Singularly enough he could write as well as ever, but it was impossible for him to read what he had just written. The memory of the *motion* involved in producing a letter, remained, the memory of its *appearance* was gone. Observe, therefore, that it was a portion of his sight memories that were gone, through sudden disease of a portion of the cells in the posterior lobe, and, since there was blindness in the *right half* of the eyes, the disease was located in the right hemisphere of the brain. (See fig. 369.) The memory of the motion used in writing, served to take the place to some degree of the lost memory pictures, for when asked to read a word, he would bring up his hand to the page, and with his finger trace the form of the letter, and then name it. It was evident that the only means he had of recalling a letter was by going through the motion necessary to write it; in other words, by calling into play his motor memories. As he was more accustomed to trace written than printed letters, it took him a longer time to recall printed words by tracing them, than written ones. But this was not his only defect of memory. He found that many objects, formerly perfectly familiar, were no longer recognized by sight. He had been well acquainted with the streets of Paris, but on going out now he looked at

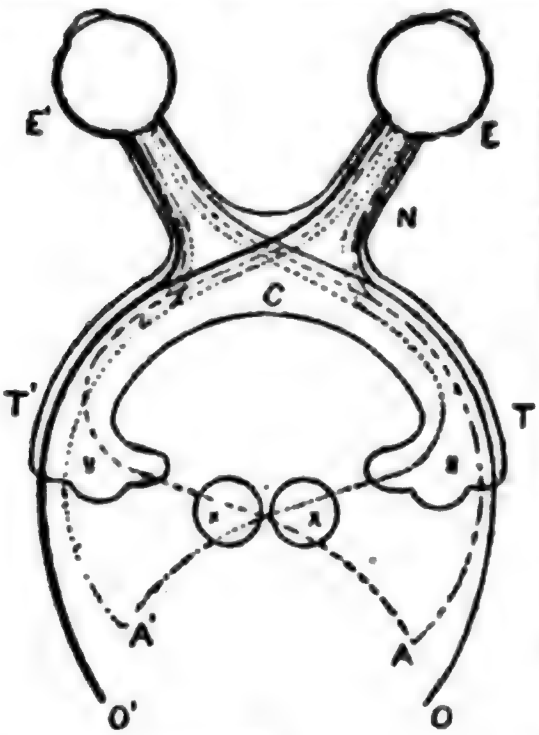


FIG. 369.

FIG. 369.—Scheme of the Optic Tracts, showing connection of the Organs of Vision, in the Cerebrum, with the Retina. The lines indicate the connections, *O* being connected with the *right half* of each eye, and *O'* with the left half of each eye. The Angular Gyri, *A*, *A'*, are connected with the central parts of the eye, especially the Macula Lutea (yellow spot). Each gyrus is connected chiefly with the eye of the opposite side, but also, to a minor extent, with the eye on its own side. For position of the angular gyri, see fig. 360, *A G*.

E.—Right Eye.
E'.—Left Eye.
N, *N'*.—Optic Nerves.
C.—Optic Chiasm.
T, *T'*.—Optic Tracts.
A.—Right angular gyrus in cortex of cerebrum.
A'.—Left " " "
O.—Right occipital lobe of cerebrum.
O'.—Left " " "

the houses and streets as those of a new, unknown city, and he was unable to find his way about. The loss of memory did not consist simply in a failure to recognize objects seen, it involved his power to recall objects formerly well remembered, places well known, faces, scenes of his childhood, &c. His other mental faculties, perceptions and memories, were not impaired, and he was not paralyzed, but he was put back as to a large proportion of his sight memories. These memories were gone, but he still retained the power of seeing, and therefore the power of acquiring a new stock of memories. As to reading, he had been put back into the exact condition of a boy just beginning to learn, and he was seen by Dr. Star "in the wards of Charcot's great hospital in Paris, studying away at

his alphabet like a school boy of six years." It is important to observe in regard to this case, that it confirms the opinion elsewhere expressed, that mental operations may be carried on by one cerebral hemisphere alone.* The fact that this man became *blind* in one-half of each eye, proves that the *whole* of that part of the sensory sight tract in the occipital lobe of that side, was ruined; both as to the actual and the potential areas. Because, if the potential area, or any part of it, had remained, he would not have been *blind* on that side, but would have simply forgotten the meaning and relationship of one-half of the billiard ball. But very evidently he had been accustomed to see the ball by both hemispheres, one-half by each. The disease was located in the occipital lobe, and the angular gyrus of the right side. By consulting the diagram (fig. 369) it is seen that the disease of the occipital lobe, *O*, would destroy vision memories of the right side of each eye. Disease of the angular gyrus (*A*) on the same side would destroy the miscellaneous memories originally stimulated by the central part of the eyes, the yellow spot. It would seem in this case that most of these memories were monopolized by the angular gyrus of the right side, so that upon its failure the visual memories vanished. But he could see, probably with the uninjured left side, and with it he could lay in a new stock.

Another Case: In the same hospital, at the same time, there was another gentleman who had suddenly lost his visual memory, so that he no longer recognized objects or faces, and could not recall the memories of the forms or colors of the most familiar things. The town in which he lived seemed an unknown place, and he looked upon everything as a stranger would. He did not know his wife and children except by their voices, and he even forgot his own appearance, and being in a large public gallery and seeing, as he supposed, some one in a doorway, barring his passage, he stepped forward to ask the stranger to let him pass, when, by the motions, he realized that it was his own figure seen in a large mirror. This loss of visual memory extended to memories of his childhood, as well as to those acquired recently. In reading a book, or adding a column of figures, it was necessary to do it aloud so that the sound memories could help to make him understand. While formerly he could remember easily what he read, he was now obliged to read aloud anything he desired to commit to memory, and thus to learn it by impressing his auditory memory. An interesting circumstance was, that in his dreams he no longer saw objects, but merely heard sounds or words. He was an artist, and of course the loss of the memory of all that he had ever learned of form and color, and all the skill and taste depending upon remembered experience, worked an en-

* This opinion is held by Longet, who cites, in proof, cases of injury to one hemisphere without impairment of intellect. See Austin Flint, IV, 257.

tire change in his intellectual character. It does not appear from this report that all the sight memories were lost, but there is nothing to show, as in the other case, which of the hemispheres was injured. Most likely, however, it was only one, and the few saved memories were in the other.

"Such a loss of visual memories may be temporary, as is well illustrated by the case of a city district messenger-boy, who found on several occasions that he suddenly lost his way, and could not recognize streets with which he was usually familiar, so that he was obliged to ask a policeman to take him to his home, where, however, in the course of a few hours he recovered his memory of places and of faces, which he had lost. In this case, which may be regarded as one form of epilepsy, the loss of memory can be explained by the hypothesis that a spasm of the arteries occurred in the posterior part of the brain, just as such a spasm in those of the face gives rise to a sudden pallor." The contraction of the blood vessels expels the blood, and deprives the cells of their essential supply.

The law that the habit of use strengthens and improves an organ in its function, applies to the brain as well as to muscles and sense organs. The converse is likewise true, that is, that the disuse of the brain, or any special part of it, leads to the loss or impairment of its functional force, and to its anatomical degeneracy. See case of atrophy of an optic nerve, no doubt accompanied by atrophy of the cortical center in consequence of blindness, fig. 377. When any external organ or any muscle is destroyed, or rendered through some accident, unable to perform its function, the brain cells with which such organ is connected, will be left without anything to do. And this inactivity will, in course of time, work the atrophy of such cells. "If, from a new-born animal you remove an eye, the nerve tract leading to the posterior part of the brain, and that part of the brain, will never be brought into use, and hence they never develop to a normal size. If a child is born blind, or loses his eyesight in infancy, the same is true, so that when in old age he dies, the posterior part of his brain will be found small and shrunken." (Dr. Star.) It is inferred that the hearing and articulating cells of the deaf and dumb are atrophied. It has been proved in hundreds of cases that disease of the articulating cells destroys the function of articulation; so that the inference of a converse reciprocity is obviously well taken. "It is known that if a limb be amputated, and the individual live for twenty years or more, the part of the brain which formerly governed the movements of that limb, and which received sensation from it, will be found shrunken and withered."

The fact that the protracted disuse of the brain cells finally involves the loss of their plasticity, fully accounts for the circumstance that all

sorts of facts are accumulated better in youth. It also shows the correlation between *large* cerebrum and *long* period of youth, maturity coming early to those animals whose capacity for absorbing facts is soonest exhausted. Protracted use of the cerebral cells, on the other hand, tends to perpetuate their youth and plasticity, so that a person who has been a student all his life can learn more at 50 than one who has been no student can do at at 30.

In order to produce a sensation some molecular change must be made in the cells of the cerebral cortex corresponding with the sense organ under stimulation. If the cortical center for visual sensations, for example, is for any reason not in working order, an object before the eye makes its impression on the retina, but produces no sensation, and, as Ferrier observes, the apparatus is like a camera without the sensitized plate; the cortical cells, when in normal condition, being comparable to a chemically prepared sensitized plate, on which the energetic rays produce a chemical change.

Consciousness in the lump, and as we generally speak of it, is simply an aggregate of sensations, some of which may be fresh from the external sense organs, but the bulk of them, especially in old and well developed brains, are usually the revivals of memories. The larger the cerebrum the more do the memories registered in it enter into the stimuli which direct motor action. The cerebral influence is small in a fish. Among the mammals it progressively increases up to man, in whose case it has, from long race habit, become so disproportionately great, that the loss of the cerebrum would make in his actions a far greater relative difference than such loss would in any of the lower vertebrates. Following this habit of action there has come about a much greater dependence of the motor organs upon the cerebrum for their control and direction. In all vertebrates the loss or destructive lesion of the motor centers of the hemispheres, is followed by complete paralysis of the muscles as to purposive or cerebral stimulation, that is, volitional action, and the possibilities of reflex action are all that remain. In the case of man, these possibilities, relatively to those of his normal state, are very small, while with the lower vertebrates they are large. A fish devoid of his cerebral lobes, still performs many intricate and well co-ordinated movements. In the case of man, the cerebral organs have gained such a relative preponderance over the lower ganglia, and so far superseded them in many of the common activities, that their loss, or atrophy, often makes him more helpless than the lowest animals.

CHAPTER LXV.

THE INTERNAL SENSES.

By the Harmonic process of Telegraphy, invented by Elisha Gray of Chicago, 1873, at least eight communications can be sent at once. "The transmitting apparatus consists of a number of steel reeds, each tuned to vibrate at a different rate, corresponding to some one note of the musical scale. One end of each reed is rigidly fixed, while the other is left free to vibrate by the alternate action of two electro-magnets, a local battery, and an automatic device for alternating the current of the battery between the two magnets at each vibration, so that the movement of the reed is rendered continuous as long as the current passes; but the rate of vibration of each individual reed must correspond rigidly with the note to which it is tuned. If a line is to be equipped for eight simultaneous transmissions, the main battery is divided into eight equal sections, which are so arranged as to be thrown alternately on and off the line at each vibration of the reed connected with that section. If, then, the first reed be tuned on fundamental C, it will make 128 vibrations per second, and by depressing the corresponding transmitting key, the particular section of the battery will be thrown in and out of the main circuit 128 times per second, and a corresponding number of electric waves will pass through the line. The next reed may be tuned on D, which, in like manner, will produce 144 waves per second, and so of the remaining six. At the receiving station a series of eight analyzers are placed in the circuit, the current passing through them all in succession. Each analyzer consists of an electro-magnet, whose armature is fixed at one end and free at the other, and so arranged as to form a vibrating tongue or reed, which is tuned to the same note as the transmitting reed to which it is intended that it shall respond. When the transmitted vibrations pass through a series of analyzers, each armature takes up its own set of vibrations, rejecting all the others, and consequently gives forth its own musical notes. The sound is greatly increased and intensified by mounting each analyzer upon a sounding box, or resonator, adjusted to its own note. The several transmitting keys break up the continuous tone into the dots and dashes of the telegraphic alphabet, which may be read from the sound of the analyzer as readily as from an ordinary sounder. Indeed, by the addition of a secondary spring attached to the analyzer, having a slower rate of vibration, it may be readily made to operate the usual Morse sounder by opening and closing the circuit. No difficulty is found in transmitting eight simultaneous communications over one wire to a distance of several hundred

miles, each pair of operators sending and receiving at the same rate of speed as in the ordinary single transmission. It is obvious that musical tones may be perfectly reproduced at any distance by this method, and, in fact, this has often been accomplished with remarkable success." (See Johnson's Cyclopedia.)

There is, to say the least, a striking and powerful analogy between the action of this harmonic telegraph and the organic apparatus which conveys external impressions to our sensorium. In the first place, the senses are each adapted to be set in motion by the impact of some special vibratory agitation; and in the case of the ear and eye at least, different divisions of the organ, viz., the arches of corti in the ear, and the rods and cones in the eye, are adapted to be agitated by different tones of the vibratory stimulation. The organs of "general sensibility" in the skin, are also susceptible to different tones of heat. All these organs correspond to the transmitting instruments of the Harmonic telegraph above described, while the receiving organs in the sensorium are analogous to its receiving instrument, and must be conceived as being so tuned as to be susceptible to the influence of its corresponding transmitter, and that alone.

The correspondence of the nerve to the wire as a conductor is equally close and striking, for the nerve bundle, like the wire, will carry all tones of stimulation, and will offer all of them to each of the receiving organs. But only one particular tone of the many conveyed, is competent to set up a normal vibration in any one of the receiving organs of the sensorium, the effect depending on the form and molecular constitution of the receiving organ.

While it has been shown to be probable that there is a degree of insulation in the bundles of nerve fibres by reason of their cases, or neurilemma, it is certain this is not absolute or complete, since the neurilemma is itself a conductor if the current be strong enough. But if we consider the exclusive nature of the receiving organs themselves, we perceive that their normal functions are not dependent upon the perfect insulation of their nerve fibres from those of their fellows. The case is parallel to that of the resonators in relation to sounds, explained in chapter 39. No matter how many kinds of vibration assail the resonator, it can only be made to respond to one particular tone, viz., its own fundamental.

External objects impress themselves upon the brain in two ways; first, directly, as when they reflect to us some form of force, as heat, light, contact, sound, &c., second, indirectly, as when we get the impression of an object, not from the object itself, but from something associated or connected with it. Thus, words by association of their sound with particular things, awaken the same impression as the original things them-

selves. We early find out that *table* is a word associated with a certain article. The sound of the word is the audible expression of that thing, just as the light reflected from it is its visible expression, and hearing the word revives the impression of the article with which the word was connected when we first learned it. So the table may stamp itself on the brain in the several ways—of light waves, indicating its form and substance; vibrations from touch, vibrations of the olfactory nerves, if, for instance, it be freshly varnished, &c., vibrations from sound, got by knocking, &c. Then, by the representative sound of the articulated name *table*, and by the written or visible representative of the *name*, the image produced by the direct modes of motion from the table itself is reproduced by the sound waves of the pronounced name, or the light waves from the written or printed name. Now, it seems all these various modes of motion, conveying impressions of the same thing, make their impressions and differentiations in different parts of the brain. While, therefore, it must frequently happen that a single incoming stimulus is able to arouse several distinct, and perhaps widely separated, receptive organs, so it must often likewise happen that the co-operation of several intermedial organs is essential to the proper performance of a motor function. This we have seen to be the case in speech; hearing memories and the memories of the motor action of tongue, lips and jaws, being involved, as well as the memories of the subject we are speaking about. If we are reading aloud, the memory of the forms of printed words, and the memory of the muscular movements of the eyes, must co-operate with those mentioned. If we accompany the performance with gestures, the memory of the muscle movements of the hands, head and back co-operate. After such actions have been performed a number of times, a large proportion of those going to make up one definite series become unconsciously automatic. Thus, the person reading aloud may pay little or no attention to his gestures, or the intonations of his voice, which nevertheless automatically execute themselves while his attention and consciousness are almost exclusively occupied with the sense of what he reads. It is obvious, therefore, that in such case the organs of the motor actions involved have become connected, through previous habit, with each other, so that when the exercise of reading is initiated, the stimulus which was directed to it by the will, flows from one to another, and causes all the parts concerned to act together. Observe they do not do this at first; the process has to be learned, and the differentiation of the organs, and their attitude of co-operation with each other has to be established by habit. Habit, then, in cerebral action, as in all other organic action, tends to the establishment and differentiation of organs. These are composed of cortical cells, which, when exposed to the appropriate stimulus, move in a definite manner, and set

up motion in definite muscles, or in other cortical organs. The muscular movements to which they give rise, constitute their "expression." The organs thus formed must relate to everything which makes such a mark upon the brain that subsequent appropriate stimulation is able to revive a recollection of it. I take it that no organ exists in the brain representing an action, event or thing, unless such action or thing can, under some condition, be brought to recollection. Organs come and go, that is, are made and unmade by use and disuse. The more things we see and hear and reflect upon, the more extensive becomes the area of the cortex, the thicker it gets, the greater the number of its fissures and convolutions, the greater the number of the cells. And, as in old age, the muscles shrink and the senses grow dim, so the cortex loses in its area, thickness and consistency. Obviously, the whole, or parts of the organs are lost, and those remaining are deteriorated in functional mobility.

What has been said heretofore leads to the conclusion that every new stimulation which reaches the cortex from without, differentiates a portion of it, so that a restimulation of that part gives a recollection of the fact which caused the differentiation, and when such recollection can no longer be revived, it is evidence that the effects of the act of differentiation have been lost. It follows, then, that all organs thus differentiated are organs of memory. But we are aware of actions going on in the brain which arouse in us sensations of objects that do not, as a whole, resemble any one thing, or combination of things we know of. They contain imitations of the elements of things in the environment, but under new arrangements, forming new combinations, not exactly like anything we know objectively, and yet so real as to be able to effect the same sort of differentiations in the cortical substance that are made by original stimuli, and which can be restimulated and recollected afterward. These interior, or wholly subjective cerebral actions, we know as works of the imagination; dreams, inventions, ratiocinations, moralizations, musical compositions, &c. There is no originality in the *elements* of these new combinations, because these have all necessarily been introduced from the environment. A vast number of these rearrangements are constantly being formed in our brains, by far the greater part of which, however, leave no permanent impression there, and presumably effect no lasting differentiation of cerebral substance. Those which do, we call "original" ideas, and they are not forgotten, at least for a time. The cortical cells erected by this sort of action must constitute organs as real as, and like those formed by the original incoming stimuli of light, sound, &c. The motive force concerned in their construction is the very same, consisting of external energy transmuted into nervous force. A great amount of this sort of action goes on in every brain, the most of which receives too little *attention* to effect a permanent dif-

ferentiation of organs, or to receive expression. When ideas are evolved which compare favorably with the standard of excellence set up in the brain of the thinker, they are imparted to others, and accepted by them in the same way they accept other ordinary external stimuli. Such stimuli, when delivered to persons of ordinary intelligence, do not stop in the mere differentiation of cells in the tracts of hearing or seeing memories, because, when a person has read the ideas of another, or heard them spoken, it is rare that he remembers the exact words of the author or speaker to the same extent that he remembers his meaning and the general drift of his ideas. These, to a greater or less extent, serve as stimuli to arouse memories of ideas formed previously, and there is an automatic rearrangement and co-ordination between the new and the old, and new nervous elements are differentiated by the newly directed nervous current; while the attention and the blood supply diverted from the mere words to the ideas expressed by them, the impression made by the words themselves, is too slight and brief to be permanent. If man were a solitary being, a much larger proportion of his organs would be devoted to the memories of original observations alone, but as he is a social animal, the greater area of his cortex is, no doubt, occupied by organs of ideas communicated to him by others. The principal part of his education consists in cultivating and practicing the habit of appropriating, collating and condensing the ideas which constitute the inheritance of the race. The organs differentiated by this process occupy an intermediate ground between the Initial and Terminal organs, and are ever ready to deflect, modify and qualify, or neutralize, the stimulations which entering by the former make their way towards the latter. They influence the greater part of our purposive actions.

The nature of the physiological action, which results in the formation of cortical organs of sense, cannot, of course, be determined positively, but it can be estimated by probable analogies. It is certain that the material for the nourishment and development of the cells is brought in by the blood, and so instant is this dependence of the cells upon the blood that their functions cannot be performed one second after the supply is stopped, as shown in fainting and epileptic fits, and when a stunning blow is received upon the head, by which the blood is for a moment expelled from the cerebral arteries.

Next, we have reason to think that no cell growth occurs except during the periods of *hyperæmia, or that state of slightly increased activity in the circulation which is brought on in states of attention. These states of attention are brought on by the force of incoming stimuli. The attention is, in fact, an incidental result, and is an indication of the force, the other and principal effects of which are the distension of

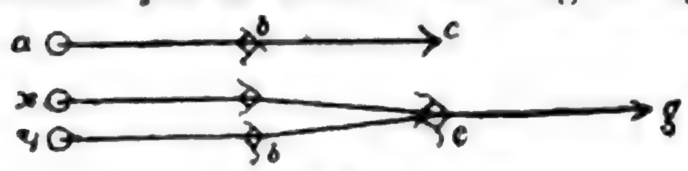
* This word is not used in the pathological sense, in which it signifies an abnormal and diseased condition.

certain of the cerebral arteries, the increased supply of blood in those arteries, and (as it appears) the immediate differentiation of old cells, and the formation of new ones.

The cortical cells of the new-born infant are there by inheritance from their parents. They are precisely in the physiological condition of the buds on a maple, or other deciduous tree, in the spring. These maple buds are formed in the fall, and remain undeveloped till the flow of sap up the tree in spring supplies the nutrient matter, and the warm sunlight furnishes the *force* necessary to cause its assimilation by the embryo leaf. So the infantile cerebral cell is a *bud* cell, and remains in an inchoate state until an appropriate nerve current, formed by the transmutation of sunlight, or some other form of energy reflected from some external object, stimulates it, and directs to it a supply of the nutrient blood. This action differentiates the cell, and forms it into a functional or active organ, so that whenever it is stimulated in the future, its reaction gives the sensation in memory of the object by which it was first differentiated. As the child grows, there is a vast increase in the number of his cortical cells. These new cells are probably formed from the old ones by budding, in a manner analogous to the budding of cells of the saccharomyces cerevisiæ (chap. 27), except that probably the process is usually much more rapid, the only condition being the presence of a superabundance of a healthy nutrient, and the stimulation of a nervous current. Supposing a patch of cells to have become differentiated by the sight of some particular object, say Minnehaha Falls. The next time we see the Falls, I suppose the new sight stimulus is directed to the same patch again, wherever that is, because the fact that it went there first shows that towards it is the route of least resistance, for that particular sort of stimulus. It is, without doubt, the hereditary route which it takes, as the patch of cells to which it goes is the hereditary patch for that sort of general stimuli, sight, sound, or whatever it may be. Upon reaching its destination, those cells which the identical stimulus differentiated before, are now only restimulated, and give a sensation of the memory of the place as we saw it before. But as it is impossible to see it twice precisely alike, there are now new elements of stimulation which must cause the differentiation of fresh cells, if there be any, or the budding of new ones from the old. So that every time we see the Falls, the idea we get of them is a combination of former or memory sensations, with new direct sensations. As there may be indefinite repetitions of such process, an organ gets to be like a composite photograph, which is made by superposing a dozen pictures upon the same plate. The reflection from the organ is a composite reflection.

The most obvious difference we discover between reflex actions of the spinal cord and purposive actions, is that the latter are due to more

than one stimulation, and must have at least two, one of which modifies the other. After the meeting of the direct stimuli at the common point where their mutual interactions condense them into one, this one stimulus goes forward as the purpose. A purposive action is therefore at least one remove further from the direct stimulation of the environment than is a spinal reflex action, although depending upon the environment just as much. The diagram fig. 370 will serve for illustration.



a, b, c.—Reflex action.
x, y.—Sense organs.
b.—Brain cells.
c.—Ganglion.
g.—Simple automatic action.

FIG. 370.

It is evident that the purpose may be many removes from the original stimuli, and may therefore be a very complicated affair, for the greater its distance the greater the number of original stimuli which enter into its make-up. It is not likely that in any complicated purpose all the original stimuli are of equal weight. Some one may be the main spring, and the others only modifiers which simply regulate the time when the action shall be performed, or the manner or the intensity of its performance.

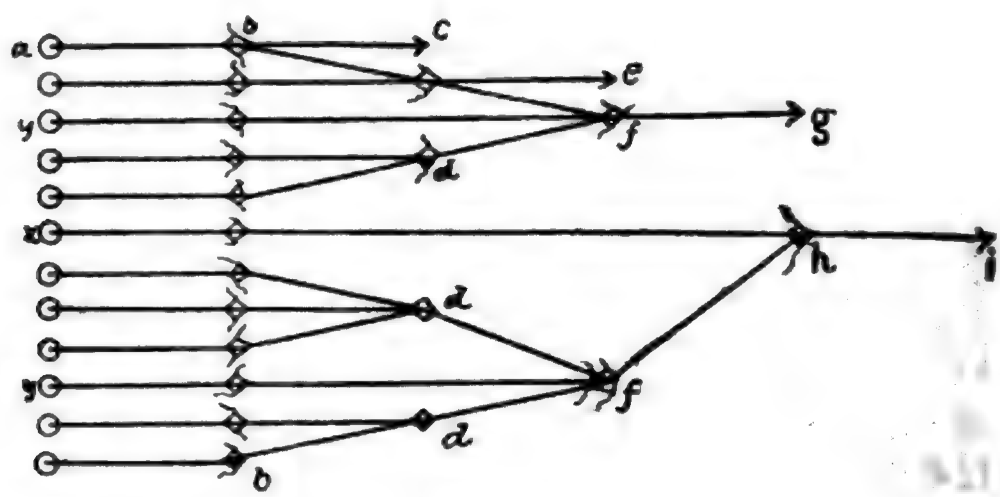


FIG. 371.

FIG. 371.—Diagram of Purposive action.
a, x, y.—Original stimuli.
b.—Reflex cell.
c.—Simple reflex action.
d.—First modification.
e.—First purposive action.
f.—Modification of second degree.
g.—Second purposive action.
h.—Modification of third degree.
i.—Third purpose.

After two or more direct stimuli have entered into composition to differentiate a common cell, such cell becomes a memory cell; that is, a subsequent stimulation of that cell will reproduce the manifestation of the same sort of action which came from it in the first place. This being the case, it is obvious that after the cells at *d*, fig. 371, have become established, they no longer depend upon the original stimuli, but may be restimulated by any one of them, or by some other associated stimulus. After a man has once seen the state-house, he need not see it again in order to describe it; any associated stimulus can re-erect the memory of it, which is then a power competent to liberate motor stimulation of

speech, &c. So we may imagine the greater part of the original stimuli out of reach, and no longer directly operative, still the ganglions at *d* will remain ready when aroused to form the motives at *f*, and after the great ganglion at *h* has been formed, all the subordinate motives which entered into it may be forgotten, and become obsolete; but let *h* be stimulated anew by any appropriate motive, and it will discharge its original characteristic energy upon *i*, that is, it re-enacts its original motor performance. It is obvious that with education and experience these ganglions of new and independent characteristics increase. In early infancy all the motives are directly from the environment; all the cells in use are of the simple character of those at *b*, and the actions are the direct reflex expressed by *c*. But in later life as the ganglions, several removes from the environment, are formed with their characteristic possibilities of action, these enter more largely into our motives. These ganglions represent possibilities of action which we properly call our *principles*. They supplement and largely supersede the original direct sense stimuli. When these principles are formed within the brain, they become a set of standard potential stimuli, ever present and ready to be thrown into activity when other parts, with which they are normally connected, happen to be aroused. We carry these principal or standard potential stimuli constantly with us, and our actions are constantly influenced and modified by them. It is as if we carried the greater part of our environment inside of us. Almost every direct stimulus from the external environment arouses one or more of them, which then gets in its modifying influence to assist in the formation of motor impulses, or in the establishment of new standard principles, or the modification of those already established. The body of these established standards, and the resultant quality and force of their mingled influences, constitute our *character*, that is to say, the probable direction which our motor action will take under a given stimulation.

The standard potentials must depend upon their respective patches of definitely differentiated cells or ganglions, which may therefore, with propriety, be called their organs, because whenever such patches are restimulated, we get the sensation of the memory of such standards. These standards relate to every definite idea, opinion and theory, upon every subject which has ever made an impression upon us, also all settled views of historical events and notions of propriety and behavior. There are standards of morality and of opinions as to what acts may be considered selfish, religious, brave, cowardly, mean, noble, kind, cruel, rash, cautious, fast, slow, workmanlike, awkward, musical, high, low, harmonious, &c., colors, beauty, greatness. Then we have standard ideas of things, what they are like. Everything we have seen, or read of, produced its impression, and differentiated its organ. Few, or none,

of these standards are absolutely correct or exact representations of the things they stand for. The way we came to think "brave," for example, was by having heard that term associated with a certain action; thereupon, whenever we afterward see or hear of such an action, we think "brave," and when we hear the word brave we think the action; that is, our standard organ for "brave" is stimulated, and yields its sensation of the memory. Obviously, no two people have exactly the same standard for anything, as no two will tell in precisely the same way, of a thing they both have seen.

Our first formed standards for qualities are concrete. Our first idea of *brave* is the whole story of some heroic action. As heroic actions multiply in our observation, we cease to be confined to the first one as our standard. As the idea, *brave*, becomes associated with so many observations, and ceases to be the peculiar property of any, it becomes more and more an abstract idea, till, finally, reference to it awakens no single instance of heroism, but the quality which is common to all the instances.

Organs are connected with each other in all directions and in the most intimate manner, so that it is always impossible to stimulate one organ without at the same time exciting some other. When we see an object that has ever been seen before, the transmuted stimulation of the light from that object reaches the organ of the object previously formed, and stimulates it afresh, causing a sensation of the thing in memory, and the stimulation goes on to some associated organ, arousing its sensation likewise. The object in the environment which initiates this disturbance, is called the "sign" of the second object whose organ is stimulated. Thus, we say a cloud is a sign of rain. That is, if I see a cloud I think of rain, because in times past when my cloud organ was differentiated, a rain organ was at the same time differentiated in association with it. And now whenever one of them is aroused, its stimulation overflows to the other and arouses it. How *much* of it is aroused depends upon the various ways in which the organ of rain is connected with other organs. For in mature persons there is a perpetual tendency to develop new associations, and to form connections between organs at first not associated. And this arises simply from the fact that in nature there are no departments. All things are united by a common chain, and as more and more of external nature imprints itself upon our brain, the more comprehensive our ideas become. We get a better focus upon nature, and objects which at first appeared huge, dim and isolated, are resolved into infinite details, and links of connection are discovered which before were invisible. Divisions and departments are subjective, and exist in our ideas because many of our organs are at first unassociated and unconnected. If we analyze common ideas which we ordinarily treat as

simple, we shall find them compound, and they grade off so insensibly into their related and associated ideas that it is difficult to tell where one ends and the other begins. In rain, the eye is impressed by the appearance of a single drop which may be seen high in the air and traced in its descent till it reaches the earth, where it strikes and bursts into many fragments. Accompanying this drop are myriads of others, subjected to the same conditions and coming to the same end. Behind these phenomena we recognize the attraction of gravitation, which causes the drops to fall, and the force of the wind, which gives them their slanting direction, and the idea of the parallelogram of forces is involved. Then there are the other accompaniments and conditions that go to associate themselves with the falling drops, as the dull and dusky sky, the wet earth, muddy roads, ditches and streams full of water, dripping trees, broken shrubbery, prostrated fields of grain, washed-out bridges, delayed mails, weather-bound travelers, thunder and lightning, and its effects in killed stock, burnt buildings, and suspension of telegraphic operations; general cessation of out-door work, loss of time and loss of wages. These, and a thousand more details, may be included in, or associated with, the general idea of rain, and the whole or any part may be restimulated or recollected in consequence of a new sight of a cloud, the sign of rain. It is obvious that in no two people would the revived series of rain associations be precisely the same, because no two have had the same experience with rain, or been placed in the same relationships to it. It would not, for example, awaken in the brain of a savage any sensation of suspended telegraphic communications, nor would he be reminded of the law of gravitation, because no part of his brain has been differentiated by such stimuli. The associations revived in the brain of a sailor would be different from those of a farmer. In each case they might influence motor action, but in each in a different way. It is, of course, owing to the difference in the surroundings and influences to which different individuals are subjected, that the fissures and convolutions vary in their details, the organs and their expressions and manifestations varying in a corresponding manner.

There is no end to the objects which are "signs" of something else. Words are signs of objects in the environment, and of states of cerebral organs. Written words are the signs of spoken words. The hunter recognizes signs of game in tracks and other indications. A flag is a sign of nationality; a motto, of sentiment. There are signs of pleasure, of discontent, of sorrow, of weariness, of cowardice, of meanness; signs of wealth, of poverty, of industry, of shiftlessness, of prosperity; signs of war, signs of peace, and signs of the times. There are signs of culture, signs of breeding, signs of morality, signs of depravity.

We artificially contrive and establish numerous objects to act as stand-

ard stimuli for the purpose of arousing the ideas in the association with which they are established. Among such standards may be mentioned portraits of friends, and all sorts of pictures, keepsakes, monuments and ceremonies commemorative of events, holidays, saints' days, birthdays, festivals and fasts, images of gods, saints, &c.

One thing is a sign of another when it causes the other to be remembered. The relationship of sign and thing signified depends upon both of them having differentiated memory organs in the brain in association with each other, the stimulation of the one called "sign" being always, or generally, sufficient to stimulate the other also. The sign may be defined to be one of a series of related details, the aggregate sum of which constitutes one general subject of stimulation, which may usually be expressed by a single general term.

A single depraved action is a sign of depravity, because such action, or its equivalent, has in some time past made its mark in the cerebral tissue, along with others of its kind, under a general class with which there is the further association of the term "depravity." Associated with the term are the ideas of the evil effects upon ourselves of such action, and consequently the feelings of aversion which it arouses. The formation of an organ which recognizes depravity in an action, is a process of the gradual spread of cell differentiations from a center by stimuli of a similar and associated kind. The great majority of such stimuli never could happen to the experience of any single individual. As each of us has this organ, it is chiefly an artificial product, the result of the accumulations of generations, imparted to each individual in the course of his education.

In early life the nuclei of the organs are scattered over the cerebral cortex, first located there according to the directive influence of heredity. These, by development and education, become organs of so many standard stimuli with which to compare the stimulus from any object with which we become affected. This object is a sign of something represented by one (or more) of our organs, and we are accustomed to say we compare this object with our standards, and place its memory alongside of its natural associations. Sometimes there is doubt, and an effort of reason, as we call it, is necessary to accomplish the proper assignment. Further reflection will show us that "we" do not make these comparisons, or direct the assignments of the new stimuli to their appropriate associations. This action is purely automatic, and could not go on otherwise than as it does.

As mentioned above, the stimulus goes of necessity to the cells which have in the past been differentiated by the same sort of stimuli. If we could imagine it to go somewhere else, no effect would come of it, for the stimulus could arouse no action, and consequently no memory in

organs with which it had nothing in common. We must conceive it, therefore, as being able to affect only unengaged (negative) cells and those which have been previously affected by like stimuli.

The revival of cells already differentiated tends to intensify their differentiation, and the differentiation of new cells by cognate stimuli tends to extend the area of the organ. As every stimulus is more or less compound, both of these results accompany the action of each of them; that is, the organ is automatically strengthened and extended by its use. The essential nature of the stimulus itself determines which of the organs shall be influenced by it. Every object, therefore, which comes within the scope of our observation, through the medium of any of the senses, automatically sorts itself out and impresses the definite area, which is alone susceptible to its influence; that is, the area which is already the seat of like impressions. We are constantly becoming aware that such automatic classifications are effected, from the fact that the new-comers stir up a recollection of the old, with which they are to be associated. On hearing a story we often say, "that reminds me of so and so I once heard." Our sensation of the relation between the standard organ and a new impression, includes a sensation of them together, and occupying definite relationships to each other. Thus, we come to be aware whether a thing is moral, religious, brave, kind, &c., by the consciousness of the sort of relationships it establishes with the standard organs.

Wagner says: "Among the convolutions of different individuals, there are remarkable differences, so that one may distinguish richly convoluted and poorly convoluted brains. These relate only to more numerous divisions, and to bendings, &c., of the primary convolutions, which retain the same number and essential position in all normal brains of whatever race. The most notable differences occur in the convolution of the frontal lobes. There are to be found brains of adults which, in this respect, resemble the brain of a seven-month's fœtus, of which it may truly be said that in their outward configuration, at least, they have remained in a fœtal condition." As a rule, when the frontal lobes are specially complex in their convolutions, it is because they are supported by well developed convolutions in the rest of the brain.

While the principal fissures and convolutions of the cortex are blocked out before birth, under the influence of heredity, a vast increase in their growth and development takes place before maturity is reached. Their growth is due to the great increase in the number of cells. It is remarkable that in these added fissures no two brains are exactly alike, and, more remarkable still, the two sides of the same brain differ greatly. Difference of education and experience in different individuals causes the different degrees of growth and increase of the various organs.

When a given tract expands as far as the brain case and the flexibility of the adjacent organs will allow, it gets further room for growth by doubling down into sulci grooves or fissures. Since these sulci occur in the organs having the most vigorous growth, and since the growth is determined by habit and education, and since these are not alike in any two people, we must conclude that the difference in fissures and convolutions between two brains is a sign of difference in education and habit and their representative organs. The existence and increase of the fissures is evidence that the organs begun in infancy from centers more or less separated, have grown laterally till they have encroached upon each other.

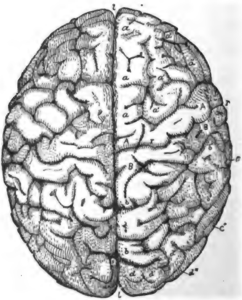


FIG. 372.

FIG. 372.—Brain of Prof. C. F. Gauss, the mathematician who died in 1854, aged 78. Brain of average size, well formed and fully developed convolutions. Note the difference in the details of the opposite sides. (From Quain, after R. Wagner.)
a, a, a. Superior, or first frontal convolution.
a′, a′, a′. Second, or Middle " "
a″. Third, or Inferior " "
A, A. Ascending "
B, B. Ascending parietal " "
b. Superior parietal lobule.
b″. Inferior " "
c. First, or Upper tempero-sphenoidal convolution.
d. First, " occipital "
d′. Second, or Middle occipital "
d″. Third, or Lower " "
l, l. Longitudinal fissure. *r.* Sulcus of Rolando.
p. External parieto-occipital fissure, appearing nearer the back end than it really is, owing to the position of the brain.

There is undoubtedly a means of communication between different or-

gans, so that the stimulation of one may overflow to another and arouse it. As observed elsewhere, our thoughts are constantly flitting from one subject to another. There are two species of this flitting. In one of these, we can, by analyzing a train of thought, discover connecting links all the way through it, and we perceive how we got over from one subject to another apparently very dissimilar one, by means of some element which was common to both. Thus, in a company let one describe a comet as rushing through space like a whirlwind, another will be led to think of the rush of an express train; another, whose attention is arrested by the idea of rushing, will be reminded of having rushed up to a supposed friend on the street, and suddenly discovered him to be a stranger; and another will remark that a mistaken rush like that might be called a bull-rush. No two objects can be named which have not some element in common. Gravity at least pertains to all, and common colors to a vast variety. The same movements of muscles may be involved in two actions belonging to very different categories. But (second) it often happens that the thought appears to take a leap over a chasm, and we are not conscious of using the bridge, if there be one. The unconscious action of the cerebrum is doubtless accountable for this, and this unconscious action depends upon an accession of blood. The pressure of blood up one artery increases the pressure in all its twigs. As these twigs may supply different organs, it is plain how as soon as one of them by use becomes slightly fatigued, the fresh one breaks out into conscious action, and our thought is, unaccountably to us, transported to a foreign subject. External objects as they come successively before our senses, give changing direction to the thoughts, and this is especially the case with children. But when we are quite out of the reach of these influences, these constant shiftings go on through the interaction of the cortical organs alone. We see, therefore, that while the organs may and do act alone, they constitute a family, and may exercise great influence over each other. An undue excitement spreads to many of them at once, and under their conflicting reactions the individual becomes "flustered," or "rattled."

While the organs may be single in their special functions, they are always more or less associated in action; some of the associations being essential to the complete performance of the action, whether it be one of thought alone, or of one involving muscular movement, while others are merely incidental and unnecessary. Thus, in the composition of an argument, memories located in various parts of the cerebrum must be revived, and in motor action many different motor memories must be involved. Incidental ideas constantly show themselves which are of no use to the argument, and incidental and useless gestures, movements and tricks constantly accompany every purposive motor movement. The

greater the intensity of the action, the more of these incidental and unnecessary accompaniments attend it. That is to say, a stimulus, if intense, reaches further and affects more organs than when it is mild. All these circumstances taken together go to prove the practical unity of the whole cortex. It is one in the same sense in which the external world is one. Built up as it is by the combined, intertwined and associated energies that are reflected from the environment, it imitates that environment in the intricate maze of connections by which every part is bound to and associated with all the rest. Anatomists tell us that if the cortex be examined microscopically no breaks of connection or boundary lines are anywhere discernible, and "that beyond a slight difference in thickness, and in the number of alternate layers composing it, the sheet of gray matter is as absolutely homogeneous as the rind of an orange, or the plaster upon your wall."

Those tracts of the cortex which are specialized organs to sense impressions, as sight, hearing, &c., and to definite motor action of particular parts, as jaws, arms, legs, &c., have become so established through the direct connections which exist between these tracts and the corresponding external sense and motor organs. These connections are confirmed to us and our posterity through the habit of the race and hereditary transmission, and do not depend upon personal or individual education and experience. The organs of perceptions and of ideas, on the other hand, have not these exclusive connections in either direction, but depending, as they often do, upon more than one class of sensory impressions, they must be connected more or less completely with all. The ideas of an artist, we may suppose, are intimately dependent upon sight memories, and those of a musician upon hearing memories, but they are also dependent upon motor memories of jaws, tongue, and limbs for their development and expression, so that the connections of the organs of these ideas are not definite and fixed, and may, by education, become formed in greatly differing ways. Where one generation after another has been educated in the same ideas, no doubt the organs of ideas do get more or less definite and settled connections, so as to become, to some extent, hereditary and fixed organs, so that we find the son "take after" the father in the bias and bent of his ideas, and consequently his character, as well as in his features. It is these intermedial organs of ideas which are subject to the formative power of individual experience and education. The formation of the organs proceeds automatically, following the differentiation of the sense tracts, and varying according to the mode of that differentiation. They become a sort of transcript of the part of the environment to which we have been exposed; a transcript which the environment is constantly at work upon, altering, adding to, expunging, and amending, day by day as long as we live and have our senses.

The internal sense organs, then, include all the cortex of the hemispheres of the cerebrum. They are of various degrees of persistency and constancy in their hereditary transmission, the older ones being the truest and most persistent. First, the older ones are of course those which relate to direct sense stimuli, as sound, sight, touch, smell and taste, and those relating to the motor actions of limbs, eyes, jaws, &c. These are common to all men, and most other mammals. Second, more recent are those relating to articulation and language, and to those narrow and partial perceptions of the relations of things which restrict the actions to the rude and savage arts of barbarous life, the practice of which exhibits characteristics we designate as cunning, deceitful, cruel, selfish, passionate, revengeful, superstitious. These, too, are common to all men now in existence, and the most of them are shared in some degree of development by most mammals. Third, more recent still in their development are the organs of the wider perceptions of relationship between ourselves and other men, aud our race and the rest of the universe. Among these may be named geography, by which we learn that our own home is not the center of the world, and probably not the most important place in it; history and tradition, by which we learn our relationships to the past and to other races, and thus discover that human excellence is not confined to our own times or to our own tribe; mathematics, by which we are enabled to perceive and compare the values of things according to their quantity; labor, by which we perceive the dependence of our comfort on the personal accumulation and care of property; religion, which is a perception of our state of subjection to unknown forces and powers in our environment which we cannot escape, and which thereupon under the influence of a false analogy we endeavor to conciliate.

The first and second classes of these organs are so fixed in our nature by heredity that they are sure to be developed in each individual, even if he be left to struggle alone for his existence. People born in civilization, if their development be not arrested or abnormal, possess the *potentiality* of the third class of organs, and the degree of development to which they attain depends upon the education and opportunity which their relationships to other men permit. They depend, therefore, upon social conditions and men's mutual intercourse, assistance and instruction. The body of the objective facts upon which these organs depend, is too great to be accumulated by one individual, or one generation of individuals; hence, while the principle of their development is precisely the same as that of the organs of the first and second classes, owing to the contingent and uncertain nature of our exposure to the necessary stimuli, the *fact* and manner of their development is, antecedently, altogether problematical. The development of the first and sec-

ond classes is assured by the direct action of the environing forces; that of the third class is contingent upon the exertion of these forces through society. It is to combinations of the perceptions of the third class that we owe the development of our ideas of morality and duty. In the order of time, therefore, it is obvious that the organs of such ideas are the latest, and they are the most inconstant and uncertain; and in the event of mental disintegration and insanity are usually the first to disappear.

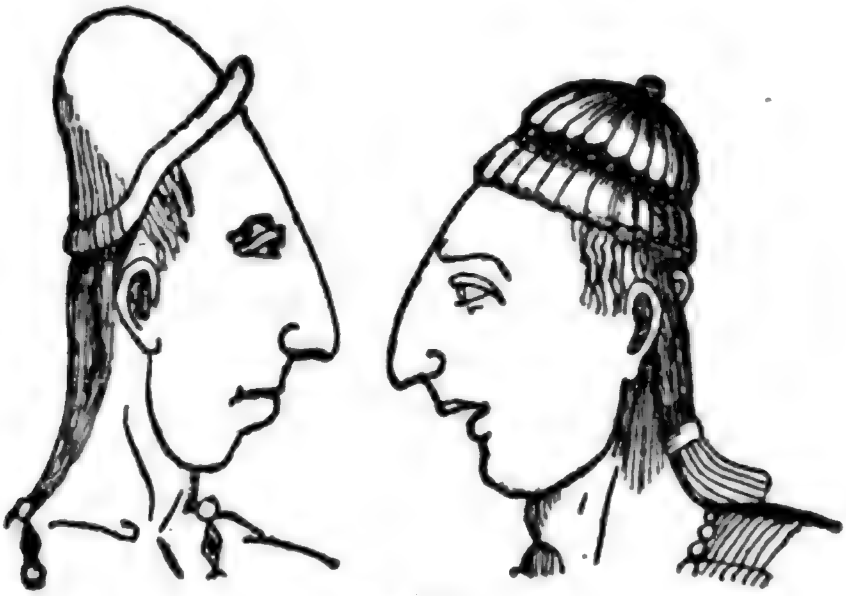


FIG. 373.

FIG. 373.—Heads of the Peruvian race from Yucatan, Mexico. (Nott & Gliddon, Types of Mankind.) In some divisions of this race in Peru, this form of head was natural, in others artificial. (Did art imitate nature in this case, or did the artificial fashion from long usage become hereditary and natural?)

Little experimental proof can be furnished in regard to the location of the organs upon which the purely intellectual states depend. Their growth develops into fissures quite as much, perhaps more than into convolutions, and probably some organs are chiefly in fissures, while others are in convolutions. Some are upon the underside of the hemispheres, and some upon their mesial surfaces. It is unreasonable, therefore, to suppose there can ever be any reliable science of bumps—or bumpology. Moreover, it is known that great distortion of the brain

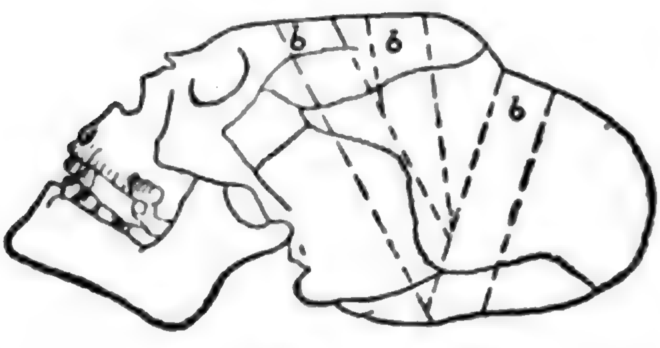


FIG. 374.

FIG. 374.—Artificially deformed skull of ancient Peruvian, the bone showing marks of the bandages used in the compression. (Types of Mankind.)

by artificial means does not essentially affect the development of the intellectual and social faculties. The ancient Mexicans and Peruvians were addicted to this remarkable fashion, but it did not reduce the average bulk of their brain below that of the other American tribes; viz., 76 to 79 cubic inches, and they must be regarded as at least equal in intellectual and social development.

The most notable difference between the brain of man and the brains of the other mammalia, is in man's greatly superior development of the frontal lobes of the hemispheres, prefrontal and postfrontal. There is also a greatly superior development of the posterior lobes. As shown by the experiments of the physiologists, the mastoid (middle) lobe is nearly all accounted for as being occupied by centers of direct sensation and motion, but when the frontal convolutions of monkeys and dogs have been destroyed, they show signs of great mental deterioration. Monkeys lose their interest and curiosity in their surroundings, and their faculty for intelligent observation. In the case of dogs deprived of the frontal regions of their hemispheres, they lose their memory, and are governed in their actions chiefly by the sensory stimulation of the moment. According to Goltz, they are irritable and restless. They can still smell, hear, taste and see, but their expression is stupid, and they are unable to steadily inspect anything, or fix the attention. "If a bone is thrown to the animal at some distance, it runs to it with great alacrity, but does not have the sense to stop at the right moment and sink its head, so that it runs beyond the mark. Instead, however, of turning round and looking for the bone in a methodical way, the animal appears to forget what it was after, and runs on regardlessly until the bone is lifted, and the animal's attention again attracted to it." They will eat meat thrown to them, as long as it remains in sight, but if they happen to lose it, will not look for it, and seem to forget they had it.

Ferrier's experiments go to show that the frontal regions contain the cerebral motor centers for the head and eyes. When these parts of the brain have been destroyed, there has followed degeneration of motor fibres leading downward through the internal capsule and foot of the crus cerebri as far as the pons varolii. The fibres of the anterior pyramids were not affected, so that the motor connections of these degenerated fibres belonged to the head and eyes, and not the limbs. It would be absurd, however, to maintain that the frontal regions contain, at least in the dog, monkey and man, nothing but the motor centers for the movements of the head and eyes, and that the great advance in this part of the brain of man, simply gives him greater facility and command of these parts. It does that, no doubt, but it does much more. Around these centers of motion lie, without doubt, those ganglia in which are co-ordinated those stages of stimulation which are preliminary to a final discharge in setting up the activities of those motor centers. The motions of the head and eyes are not so very numerous or complicated, and in man not so very much more so than in the monkey; but the purposes, motives, and varieties of stimulations which may lie behind these motor performances, may be practically infinite. Where the motives are but few, confined, as in the dog, cat, &c., to matters of

merely direct personal concern, this part of the brain is relatively small; in man it is large, because the ideas which necessitate the directing of the eyes, whose movements involve those of the head also, are vastly numerous, and include almost every conceivable subject near or remote. The stimulations which operate through these motor centers are all derived through memory centers; in short, internal sense organs lying in these frontal convolutions. A great majority of the thoughts constituted by the action of these organs, overflow into motor action for the directing of the eyes. Consider how many different ideas direct the eyes in reading, almost as many as are to be got by reading. In writing, too, every idea expressed has its corresponding creating apparatus in these frontal lobes. In every art and occupation this part of the brain directs the eyes, and in turn is reinforced and enlarged by the sensory stimulations brought back to it through the cortical sight centers. As a whole, it is an immense center of *attention*, and the eyes become the most important external organs of attention. It would be a mistake, however, to call this part, or any part, an organ of *attention*, since this term simply designates a condition of readiness for business which must accompany the activity of every sense, external or internal—hearing, feeling, tasting, smelling, judging, reflecting, comparing, &c., as well as seeing. But there is so much more of our attention associated with direction of the eyes, and their fixation upon definite objects, and in the stress of recalling the memories of such direction and fixation, that our very idea of attention usually suggests the eye as part of its necessary machinery. The very word *idea* means something seen, and a man in trying to recover a lost idea, will often put his hand up to his forehead and say, "let me see." Attention is so constantly associated with the position of the eyes that they must be taken into the account wherever attention is required. If they wander about they take attention to the things they see, and so we close them, or direct their stare into vacancy. In listening even we seem to be able to assist with the eyes. The physical expression of attention, both objective and subjective, is a fixed or riveted gaze; if objective, at the object; if subjective, into vacant space.

The large territory in the rear portion of the posterior lobe, must also be reckoned as being occupied by internal sense organs founded upon the sense of sight chiefly, but also to some extent upon that of hearing, and probably to those in which both senses are concerned. The internal sense organs, as a rule, no doubt occupy the spaces immediately adjacent to the direct sense cells through which their stimulation and differentiation first came, and so they must be found in all parts of the cerebrum. Those depending on sight are in the anterior and posterior ends of the cerebrum; those on hearing, in the sides and posterior lobe; those

on touch, in the convolutions of the mesial surface constituting the falciform lobe, and perhaps the hippocampus; those on smell and taste, in the hippocampal lobule, or subiculum. (See figs. 366, 367.)

CHAPTER LXVI.

MACHINERY OF SELF-CONTROL.

Carpenter classifies the motive powers which govern or dictate human action, under three heads. (1) Previously acquired habits which automatically incite us to do as we have been before accustomed to do under like circumstances, with little or no interference from motives of pleasure or pain, or ideas of right or wrong. Since actions done under the dictation of habit are done easily and without attention, friction, or wearing effort, we naturally and automatically fall into their performance. The moral of this is, contract only good and useful habits. Corollary: Educate the youth by the establishment of habits, moral, industrial, intellectual, &c. (2) "*Emotional states*, which incite us to particular actions by the expectation of gratification either in the act itself or in some consequence which our reason leads us to anticipate from it, or by the expectation of pain if the act be not performed." Certainly the greater part of our voluntary actions are dictated in part or whole by motives which involve a greater or less number of emotional and personal elements. (3) "*Notions* of *right* and of *duty*, which so far as they attach themselves to our actions, give them a moral and religious character." It is evident upon reflection that there can be no notions of "right and duty" which do not involve considerations relating to self, or, in other words, elements of an emotional and personal nature. So that this class of motives is, in the first instance, only a subdivision of the second class. But it may happen that in the habitual practice of the actions of this class, the personal and selfish motives become obscured and lost to view, and then there is nothing but the habit left, and the motive is reduced to one of the first class. In reality, then, we may say there are but two classes of motives; the first and second, as above.

In the great majority of moral actions, as they are taught us in our youth, the selfish element is ignored. They are enforced upon us in the first place by authority, and kept before our attention until they become matters of habit; the only reason assigned as an apology for their existence is that they are founded upon "*duty.*" This serves to silence inquiry when it does not satisfy it. Once arrived at the habit of entertaining moral feelings, and practicing moral acts, moral *character* becomes an instinct and a feature of hereditary transmission. Thus, we

find people, not a few, to whom benevolence is an instinct, and who will do a kind action because they like to, in fact, because they cannot very well help it.

That which is called self-control consists in the habitual repression of demonstrations of the emotions. The manner in which such habit may be acquired, depends upon the principal of the substitution of one sort of stimulus for another. The ingenuity of man has contrived many sorts of machines, the parts of which exercise mutual control over each other. Thus, in the steam engine, the movement of the piston through the cylinder, driven by the steam behind it, gives rise to the movement of the slide valve in the steam-chest, which movement is destined presently to cut off the motive force from the back end of the piston, and by diverting it to the front end, reverse the direction of the piston's movement. This is an example of the self-control of an automatic machine. The governor and the safety-valve are other features of the same machine, contributing to its self-control in other particulars.

When an infant is excited by something disagreeable, into a fit of passion, the nurse attempts its pacification by diversion. She calls its attention to this, that or the other agreeable sight, sound or taste, in the expectation that the stimulation from these will neutralize and counteract the one that raises the row. In children of a larger growth, the counteracting, neutralizing and restraining stimulation may be in the form of an idea presented by another person. The idea of the disapproval, anger or resentment of others whose good-will is essential or desirable to him, will in many cases have a counteracting influence against improper outbursts of passion. Such motives as these are ordinarily the most potent, at any rate at first, toward the control of passion, and they are certainly not at first literally motives of *self*-control. But after these motives have been, by external means, called up a number of times, in *association* with a fit of passion, it will after awhile come to pass that by reason of this association between the fit and the motive for its suppression, the action of the former will of itself suggest and call up the latter; and this is all that *can* be meant by self-control. Of course the reactionary motives may be in great variety, and may appeal to either physical, selfish or moral considerations, but the principle will be the same in all; namely, that at a certain development of the passion there will be an overflow of stimulation to the associated restraining motive, which then coming into action will tend to withdraw attention to itself. It is evident that the diverting action involves first the formation of a new idea through the revival of an old one, which new idea enters into the formation of a will to influence motor muscular action, or to control still further modifications of ideas which will influence motor action in the future. What we call moral self-control does not

differ in principle from the control exercised over the muscular movements by the internal senses. When a child first sees a hot stove he perhaps has a curiosity to touch it, which, in common language, he cannot restrain or control. But after he has experienced pain by touching the hot stove, *he is able* to *govern* any further inclination to touch it. That is, the first stimulation of pain registered in the memory cells of the internal senses in the cerebrum, forms a barrier to the reflex movement invited by the sight of the stove. It needs no argument to prove that the governing "*he*" in this case is the ganglion that registers the memory of the pain which accompanies the act. And its restraining power depends upon the fact of the association of the sensation of *hot stove* with the sensation of burned fingers. It is evident, then, that in some way or other the stimulus from the memory cells, registering the sensation of pain, interferes with and neutralizes that other stimulus which tends to inaugurate movement toward the stove. Every brain is for itself the center of the universe, and the rest of the body is as much a part of its environment as is any object outside of the body.

I have somewhere met with a story of a toper who was possessed with what was called an uncontrollable appetite for drink. One day, as he was about to drink, a friend endeavored by every argument to dissuade him. "No," said he, "the appetite is too strong, I cannot control it. I feel that I *must* drink this if I die for it." As he was about to raise the glass to his lips, his friend, by a rapid movement, emptied into it the contents of a small phial labled *poison*. "Then drink and die if you *must*," he exclaimed, "the sooner it's over the better." But the man set the glass down. He could *now* "control" his appetite, at least so far as that glass was concerned. Did not the environment supply the motive? That glass at first invited the man to drink it, but at last it urged him not to, and the strongest impulse expressed itself through his muscles.

It is evident that all cerebral action in which there is any association of ideas, is in the nature of self-control in the same sense as spoken of above; that is, one idea, or class of ideas, when stimulated or in activity, shares attention with those with which it is in association, and so by its own action develops limitations to such action. All "self-control" consists merely in the automatic repression or restriction of the expression of one stimulation by the interfering limitations of another. We may wish for twenty things almost at once, but we cannot perform twenty operations at once in order to get them. In the nature of things nineteen will necessarily wait for one, and one will therefore control the expression of nineteen.

We may wish to do a certain thing, but postpone it to a more convenient season. The motive for postponing then controls the action as

to time. Some other motive controls the manner of its performance. Thus, if we fear the opposition of some person, we will perform the action at some place beyond his observation or interference, &c. We form many designs and resolutions which are by first one motive and then another, remodeled, contracted, expanded, or finally undone and put aside altogether. This is done habitually, incessantly, automatically, and so rapidly that we are not conscious of very much of the action involved, unless special attention is directed to it. Indeed, after a purpose has been conceived we are entirely unable to predict what movements are necessary to carry it into execution, what movements will go along as collateral with it, or be developed from it as necessary consequents arising out of it, or be excited as opposers or modifiers. A person who can do this to a limited degree, is recognized as a person of wisdom and foresight. Every purpose is so liable to the interference of these adjunctive and cross purposes that they may all be said to exercise more or less control over each other. Whichever of the impulses to action happens to predominate at the moment, it serves to repress, obscure and conceal all the rest.

It is obvious that the sorts of ideas whose expressions thus operate as restraints to the demonstrations and expressions of others, are exceedingly numerous. In fact, every one that leads to expression at all, is of this sort, and thus exercises control in its turn, concealing other ideas while it shows itself. The ordinary intercourse of social life furnishes motives for the expression of certain conventional and habitual ideas, and the concealment of others which are more or less antagonistical to them. Protestations of regard and esteem often cover up ideas and sentiments quite the opposite. A society lady though thoroughly annoyed by the presence of an unwelcome guest, will nevertheless appear complaisant and gratified. It is said "she controls" her feelings of annoyance, and represses their expression. But suppose the "guest" be a tramp, or some other person of no influence or consideration. She no longer "controls" her feelings of annoyance, but speedily rids herself of the unwelcome presence. It is very obvious that the control exercised in the first case is due to an influence which accompanies the "guest." That is, the guest, an object in the environment, furnishes both the exciting cause of the feeling of aversion, and the motive for its concealment. In the second case, the object in the environment furnishes the exciting cause of the feeling, but no motive for its concealment, hence the difference of "expression" in the two cases.

Politeness and policy are often controlling motives, and they frequently give rise to expressions which conceal and restrain others more true than themselves. Tact, artifice, finesse, flattery, lying, and all sorts of deceit and stratagem, are expressions which may result from

these motives, and their assertion involves a concealment and control of other motives and of their expressions.

We often hear of a struggle between policy and principle, and actions are performed upon policy which are said to be contrary to principle, and vice versa. It has been observed that a principle is a standard with which to compare and co-ordinate new sensations. In order that such comparison should result, it is essential that the new sensation shall possess parts which sustain a particular sort of relationship to each other. For example, we have a principle handed down to us from the past, and erected in our brains by education and precept, that it is immoral to lie. No other sort of an action, except the telling of an untruth, can be tried by this standard. Now, in comparing every case of lying which comes to our knowledge, with our standard, a little reflection suffices to show that equally the standard is tried by the action. In saying that lying is immoral, we are, practically, comparing a number of cases of lying with another and primary standard—that of morality. And we are then compelled to seek the elements which determine what morality is. As we shall see further on, we call those acts of other people moral which we suppose will not detract from our happiness, and they judge our acts in the same way, and so the standard of morality has been practically agreed upon. Now, in order to establish that lying is immoral, a great many cases of lying must have been considered with reference to their effect on the peace and happiness of men, and the effect having been found in general to be unfavorable, the resultant of the sum of the sensations of all the experiences of lies ever had, is expressed in the formula: it is immoral to lie. But this is only a resultant, and represents the influence of the weightiest considerations. It expresses the tendency or effect of the majority of lies, but not necessarily of all. Each fresh lie may be compared with the principal standard which determines morality by determining happiness, and then it may be compared secondarily with the principle which asserts a lie to be immoral. If this particular lie tends to produce happiness instead of the contrary, it is in accordance with moral principle, although it violates the subordinate principle, and calls it in question. Evidently, if the majority of lies in the experience of mankind were lies of benevolence, the subordinate principle would never have been formulated as it is. This particular lie, then, which is under consideration, being found, as supposed, to promote happiness, it tries the principle, and, as far as its influence goes, tends to modify it. The fact that it does so, tends to show the composite and mechanical structure of the principle. A principle, then, may be described to consist of the sum of the condensations of a number of similar and homogeneous sensations or ideas associated together in one mass, as if superposed one upon another in such a way that a

characteristic, common to them all, becomes the prominent feature of the composite picture. This common characteristic is the one we see the most of, and consequently give it the title of *principle*. But the principle thus made up is manifestly nothing but the essential part of so many cases of *policy* consolidated and expressed in one formula. Principle, then, is somebody's policy. Whose? But little argument is required to show that it originates with men in the social state. No man in a solitary and anti-social condition, would interdict himself in the use of any means of stratagem for his purposes of aggression or defense, by the erection of self-imposed limitations. But men in society discovered that relations of helpfulness to each other depended upon relations of confidence in each other; lying destroyed confidence, and hence their policy came to be settled into a principle.

The social organism looks approvingly upon the action of Geo. Washington in refusing to lie about the hatchet, for his own benefit, but she equally approves his having deceived Sir Henry Clinton for her benefit. Encouraged by the applause which the social organization awards to all who work in her favor, men will strain principles in doing for their society, their party, or their country what they would be condemned for doing for themselves. Principle, then, is the policy of society, which she enforces between individuals, but which she reserves the right to violate in her own behalf according to the dictates of her interest. (See Rom. 3: 7.) If we were to revise the formula in regard to lying, with reference to this fact, we should make it read something like this: It is immoral for an individual to lie to society to her detriment and for his own advantage.

Recurring now to the question of the struggle which we say sometimes occurs between principle and policy, we perceive that it is a question between two policies, one the policy in which the interests of society are involved, the other involving the interest of the individual, regardless of those of the society. There is no question that to the individual his own interests are paramount to any others. But his personal interests are closely involved with those of the society, and society seeks by artificial means constantly to involve them still further. And where they are not so involved, she, by punishments and resentments, seeks to restrain the individual from preferring his interests to hers.

The following story was related of a negro, the servant of a Union officer in the civil war. At the battle of Corinth he ran away, and was not seen again till the engagement was over. Upon being questioned as to his cowardly conduct, he admitted: "Yes, sah, I ran away at de fust fiah, and would have run soonah if I had known what was coming." "But," remonstrated the officer, "how can we hope to succeed if men act in this cowardly manner. Don't you understand the great principles

involved in this contest?" "Yes, sah, de principles is all right, but what good'll dey do me if I git killed?" "Is your life, then, of more importance than the preservation of this great nation, and perhaps the liberation of your race besides?" "Yes, sah, it is to me, sah," replied the sable philosopher, and unless life in defeat promised to be intolerable, he was right.

Society justifies her claims upon the individual by the consideration of the great benefits and services she has conferred upon him, and the ability she possesses of rendering him miserable, but compliance or non-compliance with these claims rests at last upon the individual himself. It is in his brain that the claims of society on one hand, and her rewards and punishments on the other, are balanced. The results shown in his action, indicate the respective strength of the detachments of these two forces which engaged each other in his brain. If his action prefers the interests of society with subordinate regard for himself, we say he acts from principle; but if it prefers himself, with subordinate regard for society, we say he acts from policy. And this conclusion is not vitiated by the circumstance that policy and principle often coincide, and that what may appear to be a line of principle in the action of an individual, is in reality only a line of policy. And this leads to the further question whether, since all the action is sifted through the individual, and receives its bias and direction from his personality, it is not all likewise, so far as he is concerned, a matter of policy. The coincidence between the interests of the individual and those of the community are so close in nine cases out of ten, that a person pursuing his course under the double impulse without analyzing it, does not realize how much of either element there is in it. But let him analyze it, and he will discover that among those nine cases out of ten, not one lacks the motive of policy or self-interest, or would have been pursued if that motive had been lacking. Now let us analyze the remaining tenth of our actions, in which, I suppose, the interests of others form the principal or exclusive motive; as, for example, when we subscribe to a fund to purchase an artificial leg for an unfortunate who has lost his natural one, or to relieve starvation in some isolated settlement, or to help a burnt-out or drowned-out community in some distant state or country in which we have never been nor expect to be, or when we, at imminent personal risk, attempt the relief and rescue of persons in peril from fire or flood or pestilential disease. Since such actions, equally with the others, originate from stimuli which, arising from the environment, are reflected from our organism with the quality and direction which our personality gives them, it is evident that somehow that personality is involved with the action. In a great many of such cases we cannot discover that we are moved by what are called selfish or interested con-

siderations. We do not reflect that if we do these charitable actions we shall cultivate charitable feelings in the breasts of others, by which we may ourselves perhaps profit in case we need help in the future. Before we act, and whether we act or not, we are conscious of feelings of pity and sympathy, and these are feelings of more or less pain and uneasiness, and we find them relieved when we perform the actions to which they impel, and which are their natural expressions. We know these feelings are automatic, because there is no consciousness of the processes which occur between the sensory impression which informs us of the object of sympathy, and the sensation of sympathy which it evokes. The one inevitably and necessarily follows the other. The automatic development of this feeling or sensation of sympathy, could only occur after a relationship has been established between the brain and the object which arouses the sympathy. All automatic actions depend upon and presuppose a previous course of differentiation of organs by, and their adaptation to, a particular and exclusive sort of stimulation. Little ducks, although hatched and fostered by a hen, will, to her great dismay, betake themselves to the first pond they come to, and if restrained would no doubt experience a sensation of uneasiness. The uneasy feeling, and the act which would relieve it if they were free to do it, are automatic, and yet the little ducks never saw water before. It is evident that the relation between the water and the ducks was established in their ancestors, and inherited by them. The inherited constitution of their brain is such that the stimulation of the water by way of the senses arouses certain organs of the brain, which in turn communicate motion to the muscles, and if this motion is restrained, the stimulation begets uneasiness.

Precisely like this is the automatic tendency we all have to go to the relief of distress, and to be distressed ourselves in a degree directly in proportion to the nearness of the object to us, and inversely in proportion to the relief we are able to furnish. And we come by this automatic tendency just as the little ducks come by theirs; viz., by inheritance. Our ancestors lived in social relations for a great many generations. They called on each other for help, and rendered assistance and succor when it was required. However mercenary and interested these acts may have been at first, from long habit and cultivation in relations of intimacy and interdependence they have stamped upon the brain and transmitted to us the physiological conditions which of necessity express themselves in such acts. It is often observed that we become attached to those to whom we render service. The action begets the feeling, as the feeling would beget the action. So these ancestors of ours, compelled from the necessities of the case to help each other, came to have a care and anxiety to accomplish their task, which emotions we now

translate as sympathy. This word, which signifies ***suffering with another***, expresses the literal fact. The pressure of the environment upon the race has tended to consolidate it into a homogeneous whole. To each one of us those next to us are pressed exceedingly close. We suffer when they do, and can relieve ourselves only by relieving them.

While it is true that our instinctive actions are not reasoned out by us beforehand, nevertheless they have been performed innumerable times by our ancestors, and whether they ever consciously reasoned them out or not, the *logic* of *the events* stamped and moulded their brains, and heredity has transmitted the same kind of brains to us. To be restrained from going according to the bent of these inherited proclivities is as surely productive of uneasiness and pain as would be the restraint of the natural movements of the limbs. Every individual is born into the world with a definite organization competent to be moved in various ways by particular sorts of stimulation, and certain to be moved as soon as it is exposed to them. There is at first no control or restraint, but the stimulus which first gets access to the young animal, continues to operate it till the particular tissues with which it deals are exhausted. It is only after a certain amount of experience is attained that the conditions of harmony and inharmony in cerebral interactions, which give rise to pleasurable and painful qualities of sensation, begin to have an influence in controlling the actions. The experience consists in the cultivation and development in the individual, by stimulations from the environment, of certain activities, which, as they turn out to be in harmony or inharmony with the inherited bent, are productive of pleasurable or painful sensations. These sensations become subjects of memory, and as memories or recollections only, they enter into, or, rather, they exclusively constitute the immediate stimuli concerned in conscious voluntary action. Actions therefore tend to perpetuate their kind, and we readily see how our movements of the present time are dominated by those of the past, and how the present generation is ruled by those which have gone before.

CHAPTER LXVII.

PLEASURE AND PAIN.

The intimate nature of pleasure and pain is still a matter not settled to the satisfaction of the Philosophers. Prof. Bain quotes Kant as saying that "pleasure is the feeling of the furtherance, pain of the hindrance of life." Following this view, Prof. Bain formulates what he calls the law of self-conservation, thus: "States of pleasure are connected with an increase, states of pain with an abatement of some or

all of the vital functions." In support of this he remarks, "the pleasures of healthy exercise and of rest after toil, the pain of fatigue, the pleasures of nourishment and pure air, the pains of hunger, inanition or suffocation, the pleasures of health generally, the pains of bodily injury and disease." While he proposes this for the general law, he is obliged to admit numerous exceptions.

But *one* real exception is fatal to the theory. There are many forms of decay and wasting of the powers which are quite painless. Many chronic ailments slowly undermine the constitution without giving any warning whatever to the feelings. You may cut your finger only skin deep, and suffer more pain from it than from a degeneration of the heart, which is destined soon to prove fatal. If the law were true, there ought, it would seem, to be a proportional correspondence between great hurts and great pains, and little hurts and little pains. A rotten tooth may ulcerate, poison the blood, and destroy life with little or no pain, while, on the other hand, a slight and by no means fatal exposure of the nerve to undue heat or cold or pressure, will produce a toothache of exquisite agony. We may indulge habits of a vicious and destructive kind, which are nevertheless too pleasurable to be broken off.

Bodily pain does not necessarily depend upon the state of the viscera, or the condition of the members, but upon the relationship of the brain to those parts. Pleasure and pain are qualities of sensation, and all sensation is in the brain. Under the influence of anesthetics, all our limbs may be cut off, and our body stuck full of pins without exciting pain, because the brain is not agitated by the process. If the nervous connection between a leg and the brain is destroyed by a local lesion, the leg may be injured without limit, but there will be no feeling of pain from it. Pleasure and pain then depend upon some state or agitation in the brain cells, and any stimulus which is competent to produce that peculiar state of brain cells, may be said to produce pleasure or pain.

To a person possessing musical cultivation, inharmonious sounds are disagreeable or painful. Either of two sounds alone may give pleasure, while if sounded together they would give pain. We trace the pain in this case not to the primary action of the vibrations themselves, but to some incident of their association. The two separate agitations of brain organs occurring together, leave a condensed impression in which the two are blended in an inharmonious one. Evidently the element of pain lies in the fact of the discord of the tones in which the brain cells are agitated. Comparing these receiving organs with the receiving apparatus of the harmonic telegraph, described in last chapter, it is easy to see how two of them can be agitated at once, each one normally doing its appointed work considered by itself. Thus, the C reed and the D reed could be vibrated simultaneously, the one at the rate of 128 vibra-

tions per second, and the other 144. They do not interfere with each other in doing their work, which is simply to respond to the impulses they receive from the other end, although taken together they are far from constituting a harmonious whole. And so of the receiving organs in the cerebrum. The actual agitations which they are fitted for, they undergo whenever appropriately impelled, regardless of their relationship with each other. It is the consolidation of these agitations into one sensation that brings out the fact that as a whole they are inharmonious, and we are warranted in the conclusion that in this case at least a sensation of a whole composed of inharmonious parts is a painful sensation. In this example we have no trouble to trace inharmony to the actual mechanical vibrations which occur in the objective instruments which furnish the noise. These vibrations alternately reinforce and neutralize each other, causing *beats* and interference in the sound waves. But we must not be too hasty to conclude that this evident inharmony in the physical world necessarily produces sensations of pain or annoyance in us. Whoever has heard the discordant racket which may be produced by the simultaneous sounding of bells, gongs, drums, &c., and reflects that this is supposed to be music by one-third of the people of the world, will admit that it does not. People whose musical sense has never been cultivated (nor inherited) are not disturbed by discordant sounds.

We might mention many other examples of harmonious relationships in our environment which tend to develop in us an appreciation of them and satisfaction in them, such as harmony of color and symmetry in form. When such appreciation or sense is cultivated, its violation gives pain; but if there is no cultivation the fact of the union of inharmonious colors, or of unsymmetrical objects, produces no effect upon us. What we call the cultivation of the musical sense, the color sense, &c., depends upon the differentiation of brain cells by previous experience and habit under certain associations, and is, in fact, the erection of standards or principles, as set forth in chapter 65. Having got our standard idea of what has given us pleasure in any particular department, each new sensation is automatically compared with such standard, and if it supports and reinforces the standard, it gives pleasure; if it disagrees with such standard, and tends to detract from and subvert or disturb it, uneasiness or pain results. It requires no argument to show that this principle extends to all the customs and conventionalities of life. We have our standard ideas of the correct thing in law, religion, medicine, politics, education, fashions in dress, deportment, &c. Those things we see in the environment which confirm and build up these standards and the cerebral organs, of which they are the expression, are pleasant, while those things which are not in harmony with them,

and tend to disintegrate them, are unpleasant. The degree to which we are affected depends upon the firmness with which the organs are established, and this depends upon the amount of energy, time, use and habit which have been expended in their erection and consolidation. Those of recent origin may be disturbed and contradicted without so much pain as those of older growth and greater intensity. In fact, those of the most recent growth are often entirely subverted by new sensations. Thus, in styles of dress and architecture there is a constant evolution keeping pace with the growing development of standards of taste in symmetry and grace.

But those ideas which have stuck to us longest, and have become woven into our lives through constant use and habit, and have become adjusted to and associated with other ideas, cannot be antagonized by adverse sensations without pain. This generalization is not confined to abstract or general ideas which are shared by many persons, but is true also of those personal and special organs which each one has, peculiar to himself, and growing out of his individual experience. Thus, we say in general, a man loves his brother more than anyone else loves him. But this we find depends upon his habit of association with him. If the brothers were brought up together in *harmony*, and have shared their sensations with each other from childhood, as is most generally the case, they love each other, and because we find it so habitually, we regard it as the rule. If, however, they are separated in infancy, and brought up under different influences of religion, habits and modes of thought, there is but little in common between them, and therefore little affection. Our interest in others depends upon the intimacy and harmony of our relationship with them, and our pain at the termination of such relationship is in proportion to such interest. We may suffer almost intolerable grief at the loss of a near relative by death, but if it is another man's relative in a distant state, it hardly excites in us a moment's consideration. We suffer the pain of grief for everything we lose in proportion to the intimacy with which we have been attached to it, whether it be friend, property, influence or position. Such intimacy is the expression of cerebral organs differentiated and built up by repeated sensations of harmonious relations. It is founded upon the superposed and consolidated memories of these relations, each separately in some way promotive of our satisfaction, and, in the aggregate, of our happiness. Any sensation, which, coming into contact with such organ, tending to add to it, strengthen it, and build it up harmoniously with itself, adds to our happiness; while any sensation, which, coming into comparison with such established organ, tends to antagonize it and undo instead of furthering it, brings discord and, consequently, unhappiness. The effect of rubbing two rough bodies upon each other, is to eliminate

the points of friction and reduce them to correspondence and harmony. And so we are to conceive the action going on in organ building. There is certain to be a tendency in such action to produce a degree of correlation, mutuality and symmetry in the whole body of the cerebral organs, the aggregate result forming the basis of character, as observed elsewhere. Youth is the formative period, during which this process of harmonizing and adjusting the organs to each other is most active, and during which new sensations are received with less of a surprise to those which have been previously received. The griefs and disappointments of youth are less intense, and more speedily recovered from, than those of later years. In maturity the organs have become balanced with each other, and by their automatic interactions have become mutually adjusted, correlated and consistent with each other, so that any disturbance of one is apt to involve others. A great grief or disappointment may quite undo a whole character, or it may so derange the symmetry and balance of the organs as to produce insanity. We instinctively state the material fact when we say the man is "unbalanced." We may observe here that the disturbance of this balance may be effected by a too great joy as well as by a too great grief, as we may disturb the balance of scales by either taking away from or adding to one of them.

In further confirmation of this theory, we have the fact that the disturbance caused by the introduction of sensations of a disturbing character, depends largely on the abruptness with which they are introduced. A man losing all his property at once may be shocked into insanity, whereas, if he loses it piecemeal during a period of years, he becomes gradually adjusted and reconciled to the new conditions. So we recognize the necessity of "breaking the news" in cases liable to produce excessive grief or joy. This expression again indicates, perhaps unwittingly, the fact that a great sensation can distribute its force and secure equilibration between the organ directly affected and its associated organs with less shock if it is "broken" and administered piecemeal. On the other hand when a joke is perpetrated with the design of producing laughter, we endeavor to concentrate as much of its force as possible in its "point," so that the shock upon the organ or organs involved in its perception shall be so sudden as to cause an explosion in motor expression, which in such case is laughter. If the story is awkardly related so that the idea which should come out suddenly and at once is allowed to appear a part at a time, it may produce amusement but not an explosion. A witticism, joke or pun in order to provoke laughter must possess ideas which are in pleasant harmony, but whose harmony is not obvious till the point is reached.

It was observed that pains arising from injuries to the body are felt in the brain. The entire surface of the body and many of the internal

organs are connected with the brain by nerves of sensation. These nerves and the cerebral organs with which they connect, we have inherited from our ancestors as much as we have inherited our other bodily parts, and they exist in us at birth. They were developed together pari passu, the bodily parts, the sensory nerves, and the cerebral receiving organs. Their harmony and correspondence at birth are perfect. The process by which this correspondence has been brought about, has gone on during past ages in our ancestry and consisted in the constant association of stimuli of a certain class and degree of force applied upon the periphery of the body, with their corresponding cerebral centers. The development of the cerebral centers of sensation is such as necessary to bring them into correspondence with an *average* of the stimulations to which they are subjected. Having become so developed, any stimulations which are within this normal average will harmonize with the cerebral organ and tend to confirm and strengthen its function of sensitiveness to such sort of stimulation, while any stimulation in slight excess of such average will tend to change the organ and to make it sensitive to the new tone of sensation. When this process is going on we have a sensation of effort which is a more or less subdued uneasiness. But if the stimulation be too great to be followed by a further differentiation of the cerebral organ it is painful, because not having been built up by such stimulation it is not in harmony with it. If the skin be violently scratched with a pin it is painful, because the corresponding cerebral organ has not been built up by stimuli as violent as that. Nor, neither has the skin itself as an organ of sense been developed by such stimuli. They are both protoplasm, and what develops one will develop its correspondent. They are complementary of each other and rise or fall together.

As observed heretofore, the intrinsic constitution of protoplasm allows of its differentiation only by stimuli within certain limits of violence; with reference to temperature for example, the limits for the simplest organisms are the boiling point of water on one hand and its freezing point on the other. With the higher organisms the limits of endurable violence are greatly circumscribed. The blood of but few mammals can with safety vary in temperature more than ten or fifteen degrees F. The same thing is true of other sorts of stimuli. In order to affect us at all they must be of a certain degree of force. If the force be too great the effect is destruction instead of differentiation or healthy sensation. Sensation can be aroused only by stimuli within the limits of the integrity of the tissues involved. Gentle stimulus within those limits gives satisfaction or pleasure according to the state of the tissues; forcible stimulus begets a sense of uneasiness or disagreeableness, more forcible stimulus of pain, violent stimulus of intense pain. The most violent stimulus

being outside the limits, destroys the tissues, or stuns the sense organ or nerves so that no sensation is conveyed.

If the sensation of satisfaction arises from the impact upon an organ of the kind of stimuli by which it has been built up, we may suppose that this sense of satisfaction is the most intense when the organ is in the best state for reflecting such stimulus. There are two conditions requisite for pleasurable sensations; one is that the organ be fresh and not fatigued, the other is that the attention be concentrated upon it, and not distracted by other actions. The sense of fatigue arises when the organ has become so far depleted and worn in its tissues through the waste of action that it can no longer be stimulated by its accustomed stimulus, or is moved by it in a sluggish and inadequate manner. After the action is over, the restoration of the depleted tissues proceeds by the assimilation of fresh matter supplied by the blood. This process of rebuilding is negatively agreeable; that is, it gradually relieves the disagreeable sense of fatigue. When the organ is fully restored and rested, its stimulation by the appropriate object will give the greatest pleasure it is competent to give, provided the *attention*, that is, the blood supply, is directed to it chiefly or exclusively. If the blood flow is divided between this and too many other organs, it soon becomes exhausted and fatigued again. We are glad to entertain a friend whom we have not seen for some time, unless we should happen to have the presence of some other friend we like better, or some pressing business or occupation demands our attention. In such case, the visit will soon become irksome, which otherwise would be enjoyable. The first action of the organ under the stimulation compels a flow of blood to it, which tends to supply the new tissue as it is required by the waste of the old. If it could be forever supplied as fast as wasted, there would be no end to our enjoyment of the action. But the supply is limited, and one organ cannot monopolize it, so exhaustion and fatigue finally obscures pleasure, and puts an end to action.

It is common to distinguish between *bodily* pains and pleasures, and *mental* pains and pleasures. From what has gone before, it is obvious that such distinction is unscientific. All pains and pleasures result from agitations of the brain by stimuli from *its* environment, which includes not only every object accessible to us outside of the body, but the body itself, too, with all its parts. The principle upon which our sensations are painful or pleasurable, is just the same for all, whether they are derived from conditions in the body, or from conditions in the part of the environment beyond the body. If by bodily pains is meant those consequent upon a vicious condition of the body, then it would follow that the mental pains are those consequent upon an undesirable condition of our outside relations, our political standing, our business

affairs, our friendships, our bank account, and it would logically follow that these things constitute our "mental" part. But if it be meant that the body suffers in consequence of bodily ills, and the mind in consequence of external ills, it is untrue, since the sensations from both sources are generated in the same brain. The popular distinction of bodily and mental in this connection, then, is incorrect, misleading and unfounded in fact.

All upbuilding of cerebral organs is not pleasurable. When the brain cells are sluggish and are differentiated only by repeated assaults of the invading stimuli, the sensation developed is one of effort, and such sensation is an uneasy and constrained one. Neither is the renewal of worn-out tissue, the rebuilding or upbuilding of muscle, &c., any more than negatively pleasurable. The most of it takes place during sleep, and the more passive and insensible we are the better it goes forward. Our enjoyments come from action, and action, whether confined exclusively to the brain or accompanied by muscular movement, is accompanied by wear and waste of the parts, and consequently can not last long at a time in any one direction. On the other hand, neither is an "abatement of the vital functions" always accompanied with pain. Some diseases of the kidneys, heart and lungs, undermine the constitution and reduce the vital force without pain. Consumptives usually keep up their courage to the last moment. It is conjectured that in some cases this painlessness may be due to a poisoning or deadening of the function of the nerves of sensation by the disease in the parts affected, in some such way as the nerves of motion may be poisoned by curare, nicotine and conine. In some cases the progress of the disease is so slow that the slight sensibility which might at first exist, becomes dulled by the gradual adaptation of the patient to it. The loss of blood is not accompanied with pain, doubtless because it involves but little injury to nerves, and because it soon withdraws from the brain cells the power of sensation by abstracting their nourishment and reducing them to insensibility. Death often occurs from asphyxia by coal gas and fire damp without any warning of a painful kind. Instances have occurred in which persons in a state of syncope have inhaled ammoniacal vapors which produced violent inflammation. If the patients had been in their ordinary state, the irritation which these vapors generally produce would have warned them and caused their avoidance. People often expose themselves to the influence of cold, malaria, and zymotic infection without any painful warning, and if they avoid these perils they do it through some other stimulation than a sense of pain.

A remarkable case is cited by Carpenter of a tramp who one evening came to a lime kiln which had been filled with stone ready for burning, but had not been lighted. He laid down upon the platform at the top

of the kiln allowing his feet benumbed with cold to extend over upon the stones in the kiln. He went to sleep, and the attendants not knowing he was there lighted the fire below, and gradually the heat increased without awaking the man until one of his feet was entirely consumed, the bone being calcined. He felt no pain and did not know of his loss till he attempted to rise upon his foot when it crushed under his weight. The nerve had doubtless become too benumbed to convey the stimulus and arouse sensation. He survived the injury but a fortnight. (Carpenter's Physiology.)

Nevertheless, it is true that a large proportion of the derangement and reductions of the vital functions are accompanied or followed by pain, because such conditions put them out of harmony with their natural and habitual associations.

Likewise pleasure generally accompanies those processes which are upbuilding in their tendencies, because pleasurable sensation being sensation of concord and fitting reciprocity between an incoming stimulation and the cerebral organs already differentiated by previous similar stimulations, such new stimulation continues and confirms the work of the former ones in further building up such organs. When the stimulations originate in states of the body, they are to be taken generally as indications of harmonious and healthy action of the physical parts, the upbuilding of which is accompanied by the development of their corresponding cerebral organs. But this is not invariable. A person may get temporary pleasure from the indulgence of an abnormal appetite, for which, however, he has to pay in the pain of disappointing normal ones, which have been robbed for its development. Pleasure in vice happens only after organs of vicious activities have been erected by habit or have been inherited.

All sensations may be divided into three classes: the pleasurable, the painful, and the neutral. It may perhaps be doubted if there be such a class as the neutral, because although there is an immense class which are not either particularly painful or pleasurable, yet upon close scrutiny we might be moved to place them by a very small choice in one or the other of those classes. However that may be, at any rate the neutral class have little or nothing to do directly with our motor actions. These actions, so far as they are the results of conscious volition, are governed by motives founded upon sensations of pleasure or pain or their memories. Motives founded upon considerations of social, moral or religious duty are not exceptions. It may be said that the chief business of all sensitive beings is to avoid pain and seek pleasure, especially the former.

CHAPTER LXVIII.

CONSCIENCE, AND THE MORAL SENSE.

If all sensations were neutral in their character, that is, neither pleasurable nor painful in the least degree, they would lose their distinctive quality of sensations, and be reduced to sensory impressions. As sensory impressions, they are links in a series of motion, which, beginning as an external stimulation, passes through the sense organ and ends in reflex or automatic muscular movement. We usually attribute such automatic action to the ganglionic centers below the cerebrum. But if there be neutral sensations, that is, sensations which amount only to a passive negative sort of consciousness of the sense impression, they may contribute to a reflex action of the cerebrum, which differs in no respect from the reflex or automatic action of the centers below, except, perhaps, in being more complex in its details. There is a great deal of this semi-conscious action, and there are all grades of it, down to the point where consciousness is lost, and the action purely automatic goes on in unconsciousness. But the stimulations which go to form purposes, and carry out purposive actions, are largely, if not exclusively, made up of the recollections of sensations of a positive nature, either agreeable or painful. And the purposes are formed to perpetuate or renew those actions productive of the agreeable sensations, or to inhibit those which result in painful and uneasy sensations.

While there is no difference in principle between reflex and purposive actions, the latter appear to attach themselves to us, and to become our own. This is because the purposive actions get their stimulations from the memories of sensations aroused in us by the external sensory stimuli. The sensation is a motion of the ether contained in the internal sense cells, and it accompanies the first differentiation of these cells, and the re-erection of them, which constitutes recollection. It is therefore an indication of a permanent alteration made in our brain tissues, and this alteration is the only sort of stimulation that produces the effect of sensation in us. This, then, is no doubt the reason why actions stimulated *by* sensations (that is, purposive actions) appear in subsequent sensations (or consciousness) as peculiarly our own, while the reflex, instinctive and automatic actions of the lower centers, do not. These latter we speak of as being performed mechanically, involuntarily, instinctively, &c., while the former are said to be done intelligently, voluntarily, consciously, &c. We have small feeling of responsibility for the involuntary actions, because there is a sort of ill-defined, but correct, sense of these actions being done *through* us, rather than by us.

But there is a subjective sense of responsibility for our voluntary actions. Responsibility to what? Obviously to new sensations; that is, to consciousness. Nothing else does, or by any possibility can, concern us. Prediction is recollection referred to the future. Every purpose terminates with a prediction. In every case the prediction is of action of such a character as must be productive of pleasurable sensations. A purpose devoid of such a prediction is not possible in the nature of things. The purpose is constructed with reference to the prediction as its guiding sensation, the sensation of a present inharmony in the relations of organs constituting the *wish* or motive of the purpose. The feeling of responsibility arises as a sensation of a possible inadequacy of the purpose and its action to produce the predicted sensation. Such a feeling arises, if, after a purpose is formed, and perhaps during its execution, a hasty comparison of the present with some former action takes place in whole or in part, by which new elements of an inharmonious kind are developed to affect and weaken the prediction, which then becomes less firm and confident. When, on the other hand, the prediction is strengthened, we cheerfully say we assume the responsibility, feeling, however, so confident of the satisfactory nature of the sensation to result, that its burden is light. The principle is the same in all cases, regardless of details, which may be very complicated and far reaching. If a hunter attack a grizzly bear, his prediction and sense of responsibility will not end with his shot at the animal, but will include the action of the bear, and his own sensations after the bear gets through with him. But no matter how far the action gets away, it must at last come back to one's own personality, and (in his prediction) produce in him an effect in sensation, or else no feeling of responsibility goes with it. Thus, a purpose originating in an uneasy sensation, has an agreeable sensation for its end.

The conclusion that agreeable sensations constitute the only end and motive of voluntary action in man or beast, accords with the universal instinct of man. In all intercourse with each other and in all conceptions of other intelligent beings, as Gods, Angels and Devils, this notion appears as a settled though not always well defined conviction. (See Heb. 11:26 and 12:2; Is. 43:7.) In striving to influence men we know of no other motive to appeal to. Our pulpits, schools, laws, punishments, rewards, advice, admonition, instruction—everything by which we expect to move or influence others and make them moral, appeal to this motive.

It might be anticipated then that here will be found the basis and constructive energy underlying *Conscience and the Moral Sense.*

In a very early condition of the human race every man thought he saw his interest in the plunder and at times even in the murder of any

other persen not immediately connected with himself. Retaliation made every one a victim as well as an aggressor. After a sufficient number of ages of this sort of experience a perception of the unprofitable results of mutual robbery and distrust would begin to bore its way through even rather thick skulls, and a few families in a neighborhood would after awhile, perhaps without any very definite agreement, be found to agree not to rob or murder each other, but to put their forces together for the plunder of more distant victims. There was nothing of sentiment or far-away ethics in such first compact of government, but it was blank selfishness guided by a small amount of experience and common sense. Thus the first stage of law both civil and moral is "*Honor among thieves.*" As the means of locomotion and intercourse increased, the areas of the civil compacts would increase, neighboring tribes thus becoming bound to each other in nations, each nation a murderer, robber and thief with respect to other nations, but its component parts keeping the peace among themselves by virtue of the first principle, "Honor among thieves." The next stage of development is that in which nations, gradually discovering the cost and general unprofitableness of mutual plunder by violence, make efforts to avoid war by substituting diplomacy. In other words, the age of *violence* is succeeded by the age of *finesse*. Nations try to overreach each other by means of hostile trade and tariff regulations, and by diplomatic palaver and treaty bargains. This is the size of international morality to-day. Where men are packed together closely their development goes forward faster than where they are separated. So the moral law, as well as the civil law which is based upon it, has reached a much higher development as between individuals of the same nation than as between nations. But the steps are just the same. We pass through the age of violence into the age of cheating. Further development is the gradual suppression of the grosser and more open forms of cheating. This is done by the cheated provided they are sufficiently intelligent and have the power; and every step in the advance is a contest between the self-interest of the cheater and the cheatee. At present our law and our morality allow of large classes getting great amounts of property from those who originally earn and produce it. This is accomplished under the general operations of what are called the "laws of trade" and the "law of supply and demand." This is, of course, a great improvement over sneaking into peoples premises and stealing their property or holding them up and taking it by force. But it is far from satisfactory, and is destined to undergo a vast development in the future. The best development of moral sentiment like "the quality of mercy, is not strained" and cannot be enforced by civil codes. Pity, kindness, sympathy, affection and love are sentiments which have been developed by the intimate and mutual dependence of

men upon each other in family and other circumscribed relations. These qualities have been carefully preserved and augmented by natural selection. They are a part of our nature, inherited from the lower animals with our physical form, but greatly enlarged by our own development. It gives us as much uneasiness and unhappiness to thwart these faculties as any others; so that in the construction of moral and civil law these sentiments have their weight and influence, and find their expression in our public and private charities, our poor-houses, hospitals, asylums, &c.

The *civil law* is the embodiment of the mutual concessions each man has been compelled to make to the rest for the sake of the unmolested pursuit of his own self-happiness. The *moral law* is the theory on which the civil is founded, and from age to age it points out to men by what new concessions, which they can make to each other or can compel from each other, their stock of happiness can be increased in the long run. Thus, the moral law founded in human selfishness, and wrought out by human experience, becomes the highest and most refined expression of human self-interest. The moral code depends upon the fact that men can accomplish their selfish purposes better by co-operation and associated effort. This value of associated effort is appreciated by other animals as well as by men. Beavers, muskrats, monkeys, wild horses and cattle, wolves, buffaloes, and many others among the mammals; geese, ducks, pigeons, quails, martins, swallows, crows, turkeys, cranes, penguins, and numerous others among the birds; bees, ants, wasps, &c., among the insects, and also most species of fishes, and sea mammals, afford examples of race association for the purpose of mutual protection and defense, or for concerted aggression and attack, or for the construction and maintenance of public works for the common good.

The original prime object and motive of animal association is the accomplishment of individual ends and aims, and it of course at first takes no account of the society as such. The association among such animals as wolves and primitive men, probably began by the weaker individuals attaching themselves to the stronger. A powerful individual by his superior ability would be able to more than supply himself, and the weaker would hang around and follow him, ready to appropriate anything he might leave. From assisting at his banquets, stimulated by his example and success, they would at length assist in his aggressive enterprises, and put in a bite or a blow where they could. The society thus formed has already a tacit and instinctive moral code. I have never read that wolves, however hungry, will attack each other unless disabled, although if they did they would be no worse than savage men, or even civilized ones, who have often been known to kill and eat a fellow to escape starvation. The stronger in these primitive societies allow the weaker certain undisturbed rights, but fighting and working for

the individual good by means of the common good, are expected of all. In some communities, both of lower animals and of men, the drones, superannuated and enfeebled, or otherwise useless members, are killed off. The killing of the useless males in the bee-hive, is well known. A disabled wolf is dispatched and devoured by his comrades. In Patagonia, when provisions are scarce, the community is reduced by killing off some of the superannuated old women, rather than by killing the dogs, who are regarded as the more useful to the society. In Caucasia, when supernumerary female infants are born, they are quietly eliminated by means of a little mud stuffed into their mouths.

The crystallized customs and habits of the members of the society as they relate to each other, constitute such ethical or moral code as they possess. These are liable to more or less change, which circumstances will enforce from time to time, and they will often be violated and overridden by the more powerful or more violent members. Whatever observances of a moral kind there may be between individuals of such community, they are not applicable to any relationships outside of that community. At first, all outside of the community are the natural enemies and natural objects of plunder to those inside of it, and have no rights which they are bound to respect. The boundaries of the society in the course of social development, tend to expand. The more vital and important of the observances regulating the social life, are gradually extended, so as to embrace larger numbers. Beginning with the family, the offices and sentiment of mutuality extend first to other families, whereby tribes are formed. Next, they are extended from a tribe to its neighbor tribes, by which states are formed, then further extensions consolidate states into nations, and nations into empires. Amongst civilized men, nations and empires now form a family for certain ends, and there are certain rules of conduct which are acknowledged as binding on all men. Thus, if a man commits a murder and escapes to another nation, he is extradited, and returned for punishment. Thus, each nation renounces the right of its citizens to murder the people of other nations. The right to certain kinds of robbery and plunder is also renounced by most civilized people.

But the very civilization which operates to extend the range of moral obligation and opportunity, also extends the opportunity for all other sorts of combination. All moral considerations, as well as the civil code, do, and always must, reserve to the individual certain rights of self-seeking and self-promotion. And now it is found that of these residual selfish ends many can be accomplished better by association and combination. Consequently, we have in commercial and manufacturing enterprises, great corporations, monopolies, rings, combinations and trusts. The tendency of these rings is toward constant enlargement,

and a constant increase in the number of people interested in and dependent upon them; so that the course which their development takes is precisely that which in the first place was taken in the consolidation of people into communities for the mutual protection of themselves and their possessions against those outside of the organization. There is a constant tendency to the formation of rings within rings. Thus, in a large railroad company, whose stockholders are scattered all over the country, there will be formed a ring composed of a *few* of the influential stockholders, for the purpose of owning cars to be run upon the company's road, another ring will own all the grain elevators along the line, another will secure the coal mines, and another will form an express company. The stockholders owning these interests will operate them at the expense of the other stockholders of the general company outside of their rings, using the common road to their individual advantage. As the general stockholders become aware of this state of things, they begin to demand a share in these side enterprises, until finally they become the property of the whole company. And so it goes throughout, the tendency being the consolidation of many interests into a few, of the few into one.

These enterprises all begin in the selfishness of individuals, which prompts them to get something more for themselves than can be obtained by outsiders. The struggle for life makes all men natural enemies, and any combination or association which they make is in the nature of a truce, and an offensive alliance against the common foe, the rest of mankind. The confidence and good faith between the members of such combinations, which are absolutely essential to their existence and success, form the basis of the moral law. And the principle is the same, whether we regard a band of thugs organized to murder outsiders, but bound in honor to stand by each other; a gang of thieves in honor bound not to steal from each other; or a company of merchants in honor bound to account to each other fairly for the "profits" of their business. Let the limits of each of these organizations be extended to cover a nation, and we should have a nation free from murder, stealing and dishonesty. We perceive, therefore, that morality depends upon common interests. Common interests bring about social relationships, the harmonious reciprocity of which constitute morality, and morality ends with the advent of anti-social conditions.

Although we imagine we are civilized, our social relations must be regarded as being in a state of unstable equilibrium, extremely liable to be disturbed. Each nation has a complicated and extensive system of laws and courts for the purpose of restoring equilibrium and affording a field for the exercise of the anti-social instincts without too great a disturbance of society. And when the equilibrium between two nations is

disturbed, there being no such common field to enforce peaceful settlement, they do not hesitate to invade, murder and plunder each other. A law without penalties for its infringment would never be enforced. Neither human beings nor any other sort of beings ever did anything except upon the compulsion of motives direct or indirect. What is now called moral restraint when it is traced back to its origin is found to be the restraint of the sense of impending or threatened physical injury. Any sort of social intercourse shows men at once the liability of certain injurious results to follow the perpetration of certain offenses. In fact, the only way they could know that an act was an offense, would be by the injurious effect which followed it. A society, however primitive, imposes physical penalties in self defense, and will tend to rid itself of those members who will not conform to the law of the interests of the mass. This process will act in the formulation of a moral code, written or unwritten, and in the development of a feeling of restraint, or in other words a moral sense, as soon as the community possesses intelligence enough. But when that time arrives men also begin to take account of their general relationships to external nature. They begin to see many things they cannot understand and find themselves in the presence of forces which they cannot escape or control. They naturally do the only thing left them to do; viz., they try to conciliate these forces, and hence the idea of religious obligation arises almost as early as that of moral obligation. The essential element of all religion is the conciliation of supernatural powers which if not conciliated would be hostile. The hostility of these superior powers or gods, was at first supposed to be shown in bad crops, storms, droughts, famines, pestilences, earthquakes, defeat in war, &c., many or most of which disasters affect alike whole communities. Hence, the conciliation of the beings responsible for these disasters, naturally and necessarily became a duty of the whole community as such, and this conciliation business naturally becomes a function of the state. It is obvious that in such a matter it would be illogical for the governing authorities to allow individuals to endanger the public welfare by any dissenting action of theirs liable to neutralize or thwart the beneficial effects of the public ceremonials. In a perfectly natural way the idea became prevalent that individuals by their impiety could do this. It is related of Jonah that when he was making his voyage from Joppa to Tarshish to escape from the Lord, a great tempest arose in the Mediterranean Sea all on his account and it calmed down again as soon as he was thrown overboard. We can easily perceive from this how naturally the community would become interested in seeing that every man should perform his religious duties. Furthermore, every individual would be interested in making his neighbor contribute his fair share of wealth to keep up the public sacrifices, to build the

temples, &c. We thus discover how it is that theology with its idea of duty to the Gods has been fostered and developed as a subdivision of the moral law, and is not therefore by any means the origin of that law as the Theologians would have us believe. It has been developed and fostered by society for the supposed good of society, and so is on a par with all the other duties which the society in its instinct of self preservation exacts from individuals. Society once formed, the aggregate interests embodied by its organization far outweigh (in the general estimation) the interests of any individual. The idea has therefore been always inculcated that individuals ought to be willing to make sacrifices for the good of the community. The idea of *duty* has always included that of abnegation of self and preference of the community. It is nothing more at bottom than the triumph of great interests over small ones. It is the selfishness of the great mass making exactions from individuals.

Amongst the ancients this idea of self sacrificing duty was carried to a far-greater extent than we deem it necessary to carry it now. The Romans said, "Dulce et propria est pro patria mori." ("It is sweet and graceful to die for one's country.") It was indeed sweeter to die for it when the popular idea of duty demanded it, than to survive and bear the reproaches and persecutions one would have to endure in consequence. The public knew how to make it sweeter. Herodotus informs us that when Leonidas and his 300 Spartans had resolved to die in defense of the pass at Thermopylæ, two of the men were absent in the rear, on account of a disease of the eyes which they had. When the battle came on, one of them, Eurytus, insisted on being led into the fight, where he was killed with the rest. The other, Aristodemus, returned home to Sparta, and there he was disgraced. No Spartan would speak to him, or give him a light to kindle his fire. He was always mentioned as the craven, and they never forgave him, although he thought to wipe out his disgrace the next year by throwing away his life in the battle of Platæa. Another of the 300, named Pantites, is reported to have been sent away on an embassy to Thessaly, and so, by no fault of his apparently, he escaped the slaughter. Yet, on his return to Sparta, he was held in such contempt that he hanged himself.

Sometime about 1869 or 1870, a white man, a miner, was killed about eight miles below Missoula, Montana, and the murder was attributed to the Indians. The son of Michelle, chief of the Pend d' Oreilles, or Flatheads, "was found near the place next day, arrested by the enraged whites, and speedily hung. Before his death, his father saw him, and the young man swore that he was innocent; but his father told him that he could only be saved, or his death avenged, by a disastrous war with the whites, and asked him to sacrifice his life for the good of his people; told him to go bravely to death. There was good evidence afterwards

to show that the murder had been committed by members of another tribe, and that the boy was, as he claimed, innocent of the crime." (Clark, Sign Language, 301.)

The notions of patriotism and loyalty to the country of our birth, and of fidelity to the religion and customs of our ancestors, originating in the instinct which caused men, in the first place, to crystallize into solid and homogeneous communities, have come down to us as heirlooms. They have been impressed upon the brain of so many generations that they have become instinctive. The feeling which it requires an effort of reason to overcome is, that what was good for the father is good enough for the son; and that it is presumption, if not impiety, to endeavor to attain to a wisdom above what is written. I once heard a minister declare that a man who "went back" on the religion of his father, was no man at all.

Grote says: "The community hate, despise or deride any individual member who proclaims his dissent from their social creed, or even openly calls it in question. Their hatred manifests itself in different ways, at different times and occasions, sometimes by burning or excommunication, sometimes by banishment or interdiction of fire and water; at the very least by exclusion from that amount of forbearance, good will and estimation, without which the life of an individual becomes insupportable; for society, though its power to make an individual happy is but limited, has complete power, easily exercised, to make him miserable. The orthodox public do not recognize in any individual citizen a right to scrutinize their creed, and to reject it if not approved by his own rational judgment. They expect that he will embrace it, in the natural course of things, by the mere force of authority and contagion, as they have adopted it themselves; as they have adopted also the current language, weights, measures, divisions of time, &c." "Custom is King." Every man is born to the customs of his race, and unconsciously absorbs their spirit from his very cradle.

In all societies the individual is so largely moulded by the social environment he finds himself in, that he gets from it the far greater part of his ideas of behavior and morality, as well as the cut of his clothes. What he fails to inherit from his ancestors in the way of moral bent and inclination, is sought to be supplied to him by the education which begins in infancy, and in which both state and church take an interest. He is dominated by his social environment, constantly bent and constrained toward the average qualities of the mass. In a society of long standing, men are brought to a degree of resemblance to one another.

The necessity for co-operation and social solidity have led society into the adoption of various coercive measures to compel individual conformity. Customs, which are often invested with a supernatural or sacred

character in order to make them more binding, are, with savage tribes, of the most absolute and imperative sort, as, for example, the taboo formerly among the Pacific Islanders. Then there are the customs of caste, as among the Hindoos. The customs of the more enlightened races are almost equally rigid in some particulars, while they are more liberal and rational in others. In some savage tribes, where it would be a shocking fault to eat with a woman, it is no breach of etiquette to go naked, while in a civilized community to appear in public naked would subject a person to a term in prison or a lunatic asylum.

The influences of our social life have thus made their marks upon us, and stamped our brains full of the organs of these standards of duty toward others. Whenever our acts are in harmony with these standards, the resulting sensation is agreeable, and it is a sensation of duty performed. When our acts antagonize these standards, the resulting sensation is one of inharmony and uneasiness. The general class of sensations arising from the agitation of these moral organs, is denominated *conscience.* Conscience, then, constituting a certain definite restricted class of sensations, is a subdivision of consciousness, under which term are included all sensations of every sort. When sensations arise from actions in harmony with these standard organs, they are agreeable, and we say conscience is satisfied, or conscience approves. When the action is inharmonious, tending to wear down and disrupt the standard organ, the effect in sensation is painful, and we express it by saying our conscience checks or stings us, or brings us remorse. The principle involved is the same set forth in chapter 65. The violation of *any* habit is productive of uneasiness, which is in proportion to the intensity of the habit and the intimacy and number of its associations with other habits. The consciences of some people are very tender, and easily hurt, while others are tough and elastic.

As the drill and education by which the organs of moral sense are differentiated, are by no means infallible, it follows that the organs may stand for a factitious or made-up state of things which does not exist in reality but only in the teachings we have received; so that with the most sensitive conscience one may have totally false ideas of duty. Conscience is therefore no sure guide, and tends to keep us in the old tracks even after we have every reason to believe them wrong.

The ideas we have of good and bad, right and wrong, &c., are derived from sensations enjoyed or suffered. Those things are good the stimulations from which fit into our already differentiated cerebral organs in such harmonious manner as to produce agreeable sensations. Bad things are those which produce unpleasant sensations. In order that we may have such ideas, it is not essential that we should have actually experienced all the possible sensations. We may get the ideas

from others who have experienced the sensations, or who, if they have not experienced them, have imagined or reasoned them to be possible, and cerebral standards thus erected by precept may be as firm as any. The general idea of "good" and "bad" is supposed to have been originally based on the sense of taste. The standard thus obtained gives the basis of comparisons which have been extended into other fields. We speak of various actions as being in good or bad taste, as we also speak of persons with delicate perception and execution of the proprieties, as possessed of "tact" (touch). We speak of sweet and sour dispositions, bitter resentments, disappointments, &c. However, the majority of our characterizations of the sensations of the internal senses are necessarily drawn from those of the direct senses. Thus, the internal senses consider and ponder a thing; that is, sit down beside it, and weigh it.

The moral sense of any person is therefore chiefly the result of precept and instruction enforced by society upon him and upon his ancestors from time immemorial. Instruction and precept presuppose cerebral organs capable of being instructed. The expansion and development of the moral sentiments depend upon a corresponding expansion of intellectual force. We must be made to see something of the relationships between ourselves and other men before we can feel any sentiment of duty regarding such relationships. There can be no moral feeling where there is no intellectual perception of social relations. In the order of time the development of our moral feelings is the latest and newest, and consequently in diseases of the brain, which, like alcoholism, the opium habit, &c., let down the general vigor of cerebral action, the moral sense is the first of the faculties to suffer decay. An uncontrollable appetite by habitually superseding considerations of duty, finally sweeps them away.

When the individual suffers a loss of the wider social sympathies, he likewise suffers a contraction of moral feeling. He seeks the society of the criminal classes, and he comes to regard the limit of such society as the limit of his moral obligations. A further disintegration of the moral structure of the man, makes him deceitful and untrustworthy toward his new companions. He no longer possesses the honor that is essential to the association of even thieves. He is too narrow, suspicious and immoral to associate with criminals. But when the superstructure of morality is worn down to this extent, the intellectual foundation upon which it stands is necessarily more or less involved. Moral feeling depends upon a true perception of right social relations, and when the moral feeling has permanently vanished, it is an indication that its intellectual underpinning has become shaky, too. In other words, a low moral condition is related to, and indicative of, a low cerebral state.

either imbecility or insanity; imbecility if it is congenital, insanity if it supervenes later. And if other symptoms of insanity do not appear in the same generation, they are apt to appear in the next by heredity, because the individual is on the down-hill, and is suffering intellectual decay, and will most likely transmit an impaired mentality to his posterity.

A general unwinding of our moral natures could not take place without a corresponding degeneration of our intellect, since if the intellect were left to us it would become the basis of moral regeneration, and again construct a code of action, duty and sentiment founded on social relationships.

We may conclude, therefore, that the mere existence of animals whose nature makes it possible for them to be helpful to each other, necessarily causes them to associate together; and that this association, of inevitable necessity causes a mutual understanding of reciprocal duties between the individuals composing the association. In the case of man, his superior intellect and his power of speech render his ability for mutual assistance infinitely greater than that of any of the lower animals, consequently his mutual relationships are infinitely more complicated and far closer, and the perception of the relationships and the duties they entail are of an infinitely higher order. But the principle which underlies both cases is just the same. The causes of both are natural and material. They have laid the foundation of the moral law in lower animal life, and built it up by slow evolution to its present culmination in man.

CHAPTER LXIX.

DISEASES OF THE INTERNAL SENSES.

There are but few if any purely intellectual states of consciousness that lead to motor action. In order to become motor they must as a rule contain emotional elements. Each purely intellectual conception automatically connects itself with those ideas which involve ourselves and our relations to other persons and things, in short the emotional ideas. As such unions are apt to form wills which lead to motor activities, it is evident that if the intellectual ideas are based upon incomplete or partial sensations and recollections, they will be erroneous or only partly true representations of the objects to which they relate, and will therefore dictate actions which will be of that degree of oddity, eccentricity or insanity, which necessarily and automatically "expresses" that cerebral state. The causes which lead to abnormal cerebral action are various, such as want of proper nutrition to the whole organ, either in quantity or quality; partial deprivation of nourishment by embolism or

thrombosis whereby certain of the blood tubules are stopped up by a clot and the parts of the brain beyond the obstruction thus deprived of their blood supply; special stimulation by intoxicants, poisons and other agencies; mechanical injuries, extreme cold, old age, &c. The quality of the blood often becomes impaired through general disease And it may be supposed that the quality and efficiency of the cells and other nervous tissues themselves, likewise deteriorate through disease, alcoholism, &c. Derangement of the digestive and sexual functions reacts often upon the brain, producing hysteria, mental depression, and in some cases irritability and changeableness of temper and disposition to deceit. "In some cases recorded by M. Lallemand the most extreme mental depression was engendered by the presence of ascarides in the rectum." (Carpenter.)

The forms which insanity takes are extremely varied. It may be that the derangement is confined to intellectual processes, the emotions not being specially involved. In such cases the recollection or some special division of it fails first, so that some important element that should enter into the composition of ideas and volitions is wanting, leaving such ideas and volitions incomplete and faulty. As one after another of the memories fails, the connections and associations between ideas are destroyed, so that the cerebral movement is reduced to incoherent and unrelated ideas, which when expressed convey no sense. The will composed of the incongruous stimuli of these disconnected ideas partakes of their incoherent nature and is ready to fall to pieces and to be reconstructed by every new stimulus or suggestion. There is consequently no connected train of thought and no stability of purpose. The thoughts are like dreams.

But derangement may affect the emotional department of the cerebrum without the intellectual faculties being primarily involved. The constant and unresisted stimulation of certain feelings causes the abnormal activity of the nervous elements involved to become habitually erethised. People may become cross and irritable, passionate and violent; they may become the chronic victims of excessive and self perpetuating grief or sorrow, unless there be counteracting motives, either objective or subjective. The objective motives are such as the environment supply in resentment and forcible restraints imposed by society, or the diversion of new occupations or surroundings. The subjective motives are those supplied by one's own intellectual faculties and arise from the action of certain of the internal sense organs. The control which the stimuli from these exert upon the actions is what is denominated ***self-control*** (ch. 66). To speak with precision, there is of course no such thing as ***self***-control. The stimuli from the "internal senses" arise from ideas which have been constructed from sensations derived from environment in times

past. That is to say, the stimulus which causes a man to explode with wrath to-day, is counteracted and moderated by stimuli to which he has been exposed in days gone by.

An insane impulse is the impulse of any idea not properly neutralized and balanced by others. When any part of the cerebral cells becomes functionless from disease, embolism, or any cause, the rest receive undue stimulation, and give rise to dominant ideas. These may be innocent hobbies, or they may be insane impulses, depending on what cells are stimulated. There are whimsical ideas passing through our brains every hour in the day, which, if allowed to govern our conduct, would be called insane. In fact, the most of our thoughts and suggestions if taken singly and carried into action would be insane. Looking over a lofty precipice or high bridge is apt to suggest to everyone the possibility of falling over, and to many the idea of jumping over. If such idea were not counteracted by others of a conservative nature, it would become an insane impulse. Those who become, as it were, unwound and let down morally are subject to the domination of unbalanced ideas, which are therefore insane ideas, and result in criminal impulses.

In the case of emotional insanity it usually happens that some one of the emotions is dominant. Its impulse is a constant incentive to perform some abnormal, improper or criminal act. The fact of insanity presupposes the withdrawal or weakening of those conservative and subjective stimuli, which arise from the stock of correct and wholesome ideas constituting the internal senses of every man who has been properly educated by exposure to all the influences of a healthy environment. These wholesome restraints withdrawn, the impulse constitutes the controlling element of the will. As pointed out elsewhere, an emotion can be worked off by muscular action. If, therefore, one of these insane impulses should result in some eccentric, absurd or criminal act, the impulse, for the moment, would be satisfied and eliminated from the active stimuli, leaving the conservative and healthy ideas dominant for the time being. The victim is then full of regrets, repentance, and resolutions of amendment. But after a time the collapsed brain cells, which constitute the anatomical seat of the insane impulse, become again distended and erethised by the constantly accumulating nervous energy, the tension of which finally becomes too great to be restrained by the conservative elements, and it goes off like a spouting geyser, carrying everything before it.

The insane impulse, whatever it may be, is in all cases to be regarded as the abnormal outgrowth of a dominant idea. It is evident that those reflex actions which involve only the spinal cord, can never become excessive or abnormal from use or self-abuse, since their action depends upon external stimuli at every stage, and ceases the moment the stim-

ulus does. The same is true of those actions the stimulus for which is derived from the vegetative organism of the body. An animal which is prompted to eat only by a sense of "goneness" in the stomach, will stop as soon as the sensation changes to one of fullness. But if his motive to eat is the pleasant taste of the food, he may continue to stuff to the point of uncomfortable and injurious distension; that is, until the pleasure of the gratification of taste is counterbalanced by the pain of plethora. The motive to eat for the gratification of taste, comes from the cerebrum, and consists of the suggestion of pleasurable sensation arising from the memory cells of that sense in the cerebrum. It is the same with all the other *sensual* gratifications, their stimulations arising from the ideas originating in the cerebral memories. We thus distinguish these from the vegetative appetites which arise from states of the stomach, and other viscera, and the conditions of glandular secretions. Thus, sexuality with the lower animals is a vegetative appetite, and recurs periodically under control of the seasons, while with men and apes it is largely a cerebral appetite founded upon ideas and memories, and not limited by periodical states. It is obvious how appetites and sentiments, which depend chiefly upon ideas, may be developed without limit. And when abnormally developed, they may become abnormally influential in ruling the conduct.

An idea which has become extravagantly intensified, necessarily leads to distorted views upon everything which is founded directly or remotely upon it. It becomes a hobby or a mania, according to its force, and warps or overpowers other ideas in the formation of the will. Thus, when witchcraft was a prevalent idea, it became natural to attribute any strange misfortune or malady to the evil influence of witches. Such ideas may become epidemic, and fantastically influence the lives and characters of nations of people. The universal belief in miracles, demons, &c., during the middle ages, had such distorting effect. Individual cases of the abnormal growth of ideas to an extravagant degree, are not uncommon, and they often become instigators of immoral or criminal impulses.

An example of impulsive insanity is given of a woman in an Edinburgh lunatic asylum, in 1850. (Carpenter.) She was possessed of an intense desire to strangle somebody, it did not make any difference whom. She tried it on a number of persons, including her own nieces. In other respects her ideas were sane enough, and she was perfectly aware of the insanity and criminality of her impulse. The tendency to the disease was hereditary. Her mother and sister both committed suicide.

There is no doubt that in every community there are numbers of persons some of whose emotional ideas are in a state of chronic exaltation

or inflammation. Any occurrence in the environment which adds to this condition, may carry the excitement to the point of insanity. There are often insane actions which result from the suggestion conveyed to the brain by the performance of the action by another. Thus, the account of an incendiary fire in the papers, is very apt to be followed by other incendiary fires, the first one "suggesting" the crime to other persons who happen to be in such an emotional state that this suggestive stimulus is just sufficient to determine motor action. Executions, and other punishments for crimes, also frequently stimulate crime in the same way. Suicide and homicide are often the result of suggestion. "After the suicide of Lord Castlereagh, a large number of persons destroyed themselves in a similar mode. Within a week after the Dentonville tragedy, in which a man cut the throats of his four children, and then his own, there were two similar occurrences elsewhere. After the trial of Henriette Cornier for child murder, which excited a considerable amount of public discussion on the question of homicidal insanity, Esquirol was consulted by numerous mothers who were haunted by a propensity to destroy their offspring."

Delusions, illusions and hallucinations very often arise from disease, and they also arise from the perverted and unsound condition of the *emotional* cerebral organs. The feelings become involved with the intellectual processes to such an extent that their suggestions become elements in the intellectual ideas. Ideas so formed are of course apt to be delusions. To emotional people, the bearer of bad tidings is apt to incur aversion. So will any person whose opinions are opposed to theirs. An opponent in an argument is to them necessarily an enemy; and the argument is, on their side, pretty certain to degenerate into personal censure or abuse. The state of their *feelings* is to them the same as intellectual convictions, and, in extreme cases, have all the weight of positive, unquestionable facts.

When there is a general tendency to delusion, external suggestion is often the means of determining and particularizing it upon some one subject. In 1850 "the Queen's public visit to Scotland seemed to give a special direction to the ideas of several individuals, who became insane at that period, the attack of insanity being itself, in some instances, traceable to the excitement induced by that event. One of the patients, who was affected with puerperal mania, believed that in consequence of her confinement having taken place on such a remarkable occasion, she must have given birth to a person of royal or *divine dignity.* During the religious excitement which prevailed at the time of the 'disruption' of the Scottish church, an unusually large number of patients were admitted into the various asylums of Scotland, laboring under delusions connected with religion; the disorder having here, also, doubtless com-

menced in an exaggeration of this class of *feelings*, and the erroneous *beliefs* having been formed under their influence." (Carpenter.)

The cure for derangements of the brain centers is the diversion of the stimulus from the unduly excited parts. This is done by directing attention to other things and especially by engaging in physical labor which requires a degree of intellectual attention. Where the attention is directed, there the blood flows and so is largely withdrawn from the excited parts, and the implicated cells are allowed to collapse and by rest to recover a healthy tone. In certain sorts of muscular work very little brain supervision is required, and so the blood supplied to the brain is greatly reduced and its excitement allayed. It sometimes happens that disease cuts off the cerebrum from the rest of the system so that its action and influence are suspended. The subject is then reduced to the condition of those very low vertebrates that possess but little cerebrum. His actions are those only which are co-ordinated in the basal ganglia, cerebellum, &c. This condition is congenital in the lowest grade of idiots, and also characterizes cretins of the "first degree" who only know enough to sit in the warm sunshine or by a fire, and to go to the habitual place for food when hungry.

A case was reported by Dr. Rush of a man who was so violently affected by some losses in trade that he was deprived almost instantly of his mental faculties; he did not take the slightest notice of anything, not even expressing a desire for food, but merely receiving it when it was put into his mouth. A servant dressed him in the morning and conducted him to a seat in the parlor where he remained the whole day with his body bent forwards and his eyes fixed on the floor. In this state he continued for five years, and then recovered completely and rather suddenly.

A sailor whose cerebral activity was destroyed for a year by a depressed fracture of the skull, recovered it when the bone was raised to its normal place and the pressure relieved. During the year he passed the time in the same way as the man reported by Dr. Rush, and after his recovery the period of his illness was a blank to him; he retained no recollection of anything concerning it. (Abercrombie.)

In these cases the cerebrum was cut off entirely from influence over the motor actions and also was deprived of the function of forming ideas. The latter function depends upon the access of stimuli from the senses, and it might and sometimes does exist when the motor connections from the cerebrum downward are partially or entirely devoid of activity. That is to say, a man may be conscious of the possession of ideas without any power to give them expression in muscular movement. This is true in those cases of semi-trance in which the subject hears and understands all that is said, perhaps even plans for his own burial, without the abil-

ity to move a muscle in speech or gesture. When the cerebrum is cut off entirely, both in the sensory and motor connections from the rest of the cranio-spinal axis, the actions of the subject are no longer what is called *intelligent*, but are to be classed as *sensorial* and *automatic.* As shown elsewhere, the memories which are established by habit in the spinal cord, the cerebellum and the basal ganglia, are chiefly if not exclusively the memories of *processes* and not of special and distinctive *events.* So that when the distinctive memories which belong to the cerebrum are cut off, the movements are dictated solely by the direct influence of the external stimuli acting along the habitual routes, and producing the habitual reactions uniformly and without modification by ideas. And there being no distinctive record in memory organs of the actions, they are never recollected.

A remarkable case is reported of a young woman of Shoreham, England, who fell into a river and was nearly drowned, in consequence of which her cerebrum lost its influence upon her actions for a year. She partly recovered from the first shock of the accident, but ten days afterward was seized with a fit of stupor lasting four hours. When this was over, she was found to have lost all her memories and mental faculties, the power of speech, and the senses of hearing, smell and taste. The senses of sight and touch were acute, and various reflex or automatic movements were excited through them, but no purposive actions. Nothing that she did was remembered, her cerebrum being out of use, and no memory organs being differentiated. Her past memories and knowledge of mother and friends were all swept away. Her appetite and digestion were good, and she would eat anything put into her mouth, regardless of its taste, that sense being abolished; she never voluntarily fed herself, but if her mother started her by conveying the spoon to her mouth a few times, she would keep up the operation by herself. But she did not remember this from one meal-time to another, but had to be started for each occasion. We are reminded by this of the performance of the frog destitute of his cerebrum, mentioned in a previous chapter. The two cases are no doubt the same. The stimulation to the self-feeding action was in the hungry viscera, and, while the hunger lasted, they would continue to furnish the stimulation to the muscles after it was once directed there by being started; the associated movements following each other in the definite rythm in which they were set going.

An automatic action which she took up of her own accord was picking at the bed clothes. This is common with the old and the insane, who have lost their cerebral anchorage, the fingers being then operated by the lower centers reflexly, and without object. Her attendants gave her part of an old straw bonnet, which she picked into small pieces, then she was supplied with roses, which she also reduced to minute

fragments. After this, she began arranging the fragments she had made into rude imitations of roses and other flowers, an indication, it would seem, of a beginning in the construction of new memory organs in the cerebrum; since it is scarcely to be supposed that such memories could be developed in connection with the lower ganglia. Next, she was taught, by a little instruction, to make patchwork, and she pursued this occupation every day without intermission, till stopped by darkness. After this she was instructed in worsted work, in which she was equally assiduous. Her memory of her work never lasted over night, she began something new each morning instead of continuing her work of the day before, unless it were placed before her. She had a lover, who, during the early part of her illness, came every day to see her. His *presence* was agreeable to her from the first, but after a time she came to *anticipate* his coming, and to show disappointment if he did not come. So memory organs came to be formed with reference to him. She gradually acquired a stock of memories on various subjects connected with her experience and occupations at that time. But these were grouped to themselves, and not connected in any way with the cerebral memories of the period before the accident. They constituted a new family and a second mental state entirely disconnected from the first. At this period she was subject to emotional excitement, which three or four times a day threw her into a condition of insensibility, accompanied by a spasmodic rigidity. She also fell into this state after her attention and her eyes had been for a long time intently fixed upon her work. Nearly a year after the accident, she found out that her lover was paying attention to another woman, and the jealousy aroused thereby often brought on her fits of insensibility, and one of these at last, of unusual severity, had the remarkable effect to restore her to the mental life she had experienced before her accident. She awoke as if from a sleep of a year, the events of which were now a perfect blank to her, as she remembered nothing of what had taken place during that time. She was restored to her former memories and stock of knowledge, and to the faculty of speech, and the use of all her senses except hearing. This, however, gradually returned to her. Whatever memories she had constructed during the year of her illness, were totally unassociated with those belonging to the period before the accident. The first spasm laid an embargo of paralysis upon all the cerebrum then differentiated into memory organs, together with their nerve connections. The final spasm raised that embargo and placed it on the memory organs formed after the accident. We shall meet with further examples of this sort. By comparing the actions performed by this patient during the first half of her illness, with what is said in chapter 60, it appears that a very considerable part of them may have been automatic

and unconscious. Even the patchwork may have been performed by the ganglia below the cerebrum.

In old age the cerebral cells become "more or less infiltrated with fatty granular matter; they cease to be transparent and shrivel up. They lose their susceptibility to be moved by stimuli, and if moved they relapse easily, that is, they soon forget. Early memories are retained by the aged, but recent impressions fade. They find it hard to learn and retain new things, as names, new words and their meaning, as in a foreign language; or to acquire a technical education. This decay of the ability to learn new things, makes the passage of time seem more rapid to the old. Each new sensation registered in the brain, is a sort of time-keeper, and if no sensation were to be registered for a period of years, we should not know that such a period had elapsed. When people constantly dwell in the past, it is an indication that present events are not making lasting impressions on their brain. Demented persons who have spent many years in an asylum, will constantly dwell upon the ideas they had before their entrance, and having little power to remember sensations of events during their stay, imagine the time to be much less than it really is.

It frequently happens that where there is an injury to the cerebrum the memory of the events which happened just preceding the accident are permanently obliterated. In such case it is probable that the blood, which is directed by the stimulation to the organ under its influence, is by the shock of the accident driven away with the plastic materials it carries; so that the constructive process upon the organ is instantly interrupted before its completion.

Sir H. Holland in company with a German inspector explored two deep mines in the Hartz mountains one day and became greatly fatigued and exhausted, so much so that he lost the power of speaking German. Every German word and phrase escaped him, and it was not till he had taken *food* and *wine* and been at *rest* for some time that he recovered them.

A gentleman who suffered a blow upon the head, in consequence of it, lost the memory of the Greek language which he had acquired, but his memory was not affected in any other way.

A case is related by Carpenter of a lad who received a blow on the head by which he lost the recollection of all the music he had ever learned, but nothing else.

In another case a surgeon was injured in the head by a fall from his horse. On recovering from insensibility he gave minute directions for his own treatment, but was found to have lost all recollection of having a wife and children, but this memory returned after three days.

There are various conditions in which the power of the will to operate

the motor nerves is suspended. Some of these cases are referable to hysterical paralysis in which the trouble is in the *belief* in the ability to make the effort. Others which show the same practical results are caused by the failure of the cells concerned in the chain of the transmission of the motor impulse. In each of the cases the failure is due to a deficiency of the blood supply to some particular set of the cells concerned in the complicated process of forming and carrying out a will. This might result from embolism or from temporary paralysis or contraction of the blood vessels. In one case the capacity of the artery supplying the diseased part was contracted in size by a morbid deposit on its lining membrane.

Maudsley observes that in cases of acute mania the patient is often seen struggling to prevent the manifestation of his insane impulse. It is said he has greater "control of himself" when he is watched or remonstrated with, which means that the watching, &c., contributes a reinforcement to the conservative elements in his internal senses which restrain the insane impulse. An insane impulse is often largely a reflex or consensual impulse; that is, it is instigated directly by some object in the environment, and if the patient is kept away from the object he will not experience the impulse. If his impulse is to jump out of the second story window, make him live in a one story cottage, &c. In such cases the sensible idea suggested by the object is not overruled by the restraining action of the internal senses. It is these internal senses which regulate and moderate the energy of the lower ganglia. A fish destitute of internal sense organs, will under the merely reflex stimulus of the water swim on and on for no object, till exhausted.

What Maudsley calls congenital defects of the will would be more properly named the inheritance of defective organs of internal sense; that is defective organization of the cerebrum, either in the cells relating to the memory or in the nervous connection between those cells, whereby they are co-ordinated and made to modify each other. Children are sometimes born having an incorrigibly, vicious and anti-social nature and totally without conscience. They are almost always descended from an ancestry tainted with some form of nervous or brain deficiency, epilepsy, insanity, &c. In a large proportion of such cases, the functions lost or aborted are those related to the social development of the race and which in the order of evolution have been the last to make their appearance. It has been repeatedly observed that the latest accession of bodily differentiations and functions is less firmly fixed than those of older habit, and in the case of atrophy the most apt to suffer. There are great differences in different stirps and families in regard to the particular line upon which their latest differentiations have run. Thus while some exposed for generations to the influence of social and reciprocal intercourse have become considerate.

sympathetic and benevolent, mindful of the rights of others and imbued with an instinct to put themselves into co-operative harmony with their fellows ; others whose ancestry have lived apart and relied upon themselves, and especially those whose ancestry lived in conditions of antagonism, as banditti, pirates, soldiers, adventurers, &c., have inherited a less social and co-operative spirit. Very few people can trace their pedigree more than five or six generations, and it is seldom practicable to tell what sort of blood underlies the mild and civilized behavior which appears upon the surface of modern society. When atrophy occurs from any cause in any family, the polish lately put upon the surface by the attrition of social intercourse is quickly lost and some of the ancestral conditions are laid bare. These conditions may be immoral or anti-social to a greater or less degree ; or the effects may involve deeper strata and more remote ancestries, taking us back to the infancy of the race. Maudsley tells of such a case. A boy of eight years, who, though quick of perception, was unstable and unable to fix his attention long enough to learn anything even a game of hoop. He was ingenious in mischief and delighted to talk of playing malicious tricks, in the imaginative description of which he exulted in a braggart and grotesquely dramatic fashion, chattering incessantly and running from one thing to another. He had a minute memory of past events, but no regard for the truth in relating them, lying simply for its own sake. He was fond of talking in a ludicrously fierce and boastful tone of killing persons or animals by whom he imagined himself offended. His father had been insane and his paternal grandmother demented. There was also insanity on his maternal side, and his mother was an unstable, excitable and insincere person. [1] The stock had evidently backslid in some lines, and this boy was no doubt very monkey-like in some of his cerebral characteristics.

But if we repeat in individual life the steps in progressive development that have been taken by our ancestral line, there is a period in the life of each when the character is of the anti-social, selfish and unmoral nature, attributed to the brutes, although it is also true that the rudiments of social and moral restraint are laid in brute society.

Children are, as "La Bruyere described them, naturally boastful, scornful, passionate, envious, curious, selfish, idle, prone to steal, apt to dissimulate, easily moved to immoderate joy, or thrown into excessive grief by trifles, not willing themselves to suffer, but eager and pleased to inflict suffering." This description applies also to some savages, but not in all respects to all, nor to all the children of civilized races. But the unselfish and moral traits, which owe their cultivation and development to the social habit, are, as a rule, quite wanting in children, however civilized.

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[1] Body and Will, 249.

It is not necessary to suppose the interposition of some foreign, supernatural, or diabolical influence, in order to account for the freaks of insanity, imbecility and mental perversion. Cases of this kind, where they are congenital, are, without doubt, due simply to arrested development. The imbecile is left, so far as regards certain cerebral conditions, in a state through which other people pass. If a foundry-man attempts to fill a mould with a deficient quantity of metal, the lower parts of his casting may be perfect, while the top parts are defective, or wanting. So the half-made-up condition of the imbecile brain, suggests a deficiency of material and of the vital energy necessary to its assimilation.

According to Maudsley, almost every kind of mental disorder begins with a moral alienation of greater or less degree, which becomes more pronounced and intensified as the disease advances. The patient is apt to become coarse, indecent, unchaste, reckless in business matters, uncandid, tricky, deceitful and dishonest. He loses his natural affections, and is apt to look upon his best friend as his enemy. The offspring of people who are mentally deranged, are very apt to show moral deterioration.

In general paralysis we still see the same breaking down of the latest centers as constituting the beginning of the disease. Its effects in the beginning are very like those of intoxication in its earliest stages. It is due to pressure of the blood upon the nervous system, especially the brain. Sometimes there is effusion of the blood or of serum, sometimes a turgescence or swelling of the blood vessels. This pressure prevents the participation of certain brain cells in the formation of will, so that it is formed imperfectly, and, in regard to motor action, perhaps not at all, as relates to certain divisions of the nervous system.

The demoralizing effects of alcohol and opium are well known. Persons addicted to their influence are not very strongly bound by any moral considerations whatever. Their wills are made up by motives, among which moral considerations are not included. So we are accustomed to say such persons have lost control of themselves. The restraining effects of the ganglia of the moral senses are left out, and those of the selfish layer below remain in full control. So that the regard for others, and for those relations with others, which constitutes the substance of morality, is, for the time being, obliterated. Excessive alcoholic stimulation may, and often does, permanently pervert the normal nutrition of the nervous system and brain. When drunkards become parents, they transmit a defective nervous and cerebral organization. Their offspring are nervous and hysterical, weak, wayward and eccentric, or they may have a tendency to insanity, or, in extreme cases, they are congenitally weak-minded or idiotic. In Massachusetts, out of

300 idiots, it was ascertained by Dr. Howe that the parents of 145 were habitual drunkards. "In one instance, in which both parents were drunkards, seven idiotic children were born to them."

It happens quite frequently that the commissures, or some of them, are deficient, reducing the brain, in this respect, to that of the marsupial. A case is cited of a servant girl, in whom, after death, it was found that "the middle portion of the fornix, and the whole of the septum lucidum, were absent; and in place of the corpus callosum there was only a thin fasciculated layer of fibrous matter, one-fourth of an inch in length, of which, however, the fibres extended to all the parts of the brain into which the fibres of the healthy corpus callosum can be traced. The middle commissure was very large, and the lateral part of the fornix, with the rest of the brain, was quite healthy." There was nothing peculiar about the mental manifestations of this girl, except a want of forethought and power of judging of the probable event of things. Her memory, morality, temper and disposition were good, and her information equal to that of others of her class.

Another case is on record in which the anterior part of the corpus callosum was deficient, together with the middle and anterior portion of the fornix, and the whole of the septum lucidum. In this case, there was marked intellectual deficiency, accompanied by dullness akin to stupidity. (Carpenter.)

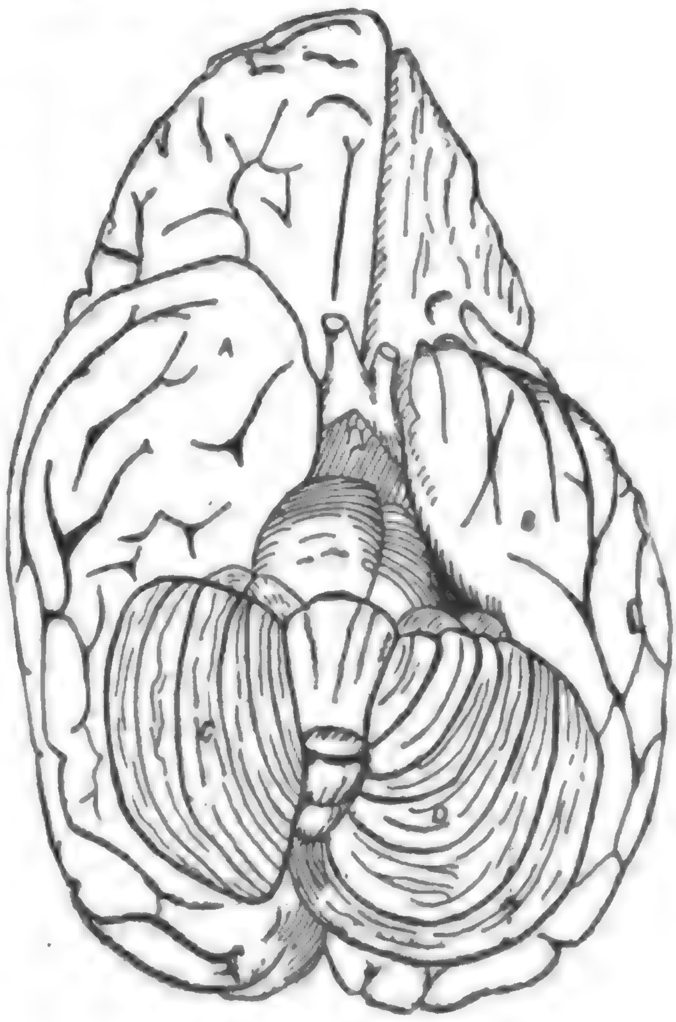

FIG. 375.—Base of brain of an insane woman, showing atrophy of the front end of *left* hemisphere B, accompanied by degeneration of the *right* lobe of the cerebellum C.

Figure 375 shows the appearance of the base of the brain of "a woman who, after the age of thirty, became suddenly aphasic and hemiplegic on the right side. She became insane, murdered her two children, and was committed to Broadmoor Asylum, where she died twelve years after the occurrence of the paralysis. The whole of the cortex in the front end of the left hemisphere, together with the corpus striatum, had entirely disappeared, and been converted into a cyst full of fluid." The pyramidal

FIG. 375.

tract of the left side had undergone secondary degeneration, and with it the right middle peduncle and right lobe of the cerebellum had become greatly reduced." (Ferrier.)

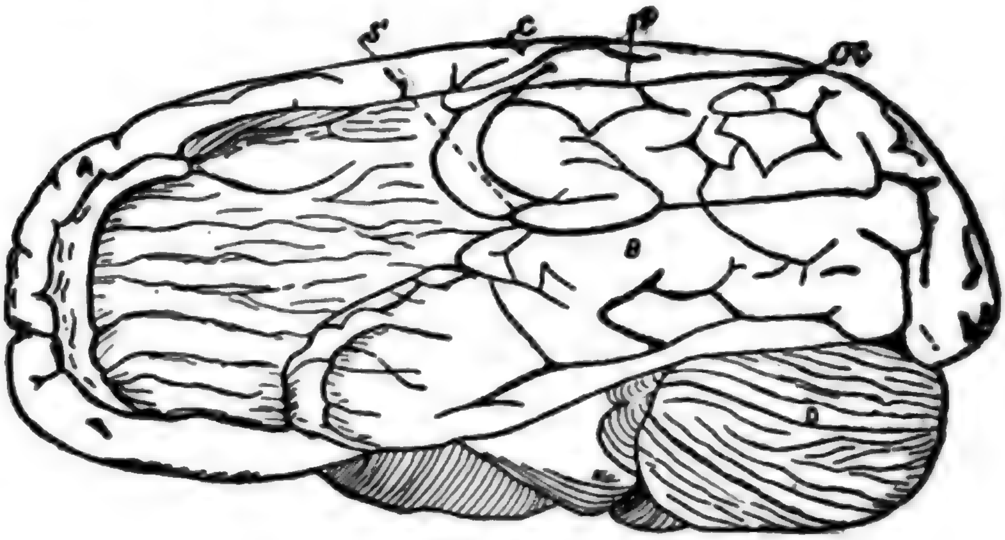

FIG. 376.
FIG. 376.—Same brain shown in fig. 375, seen here from the left side.
A.—Right hemisphere. B.—Atrophied Left hemisphere.

"It is stated by Foville that in acute cases of insanity he has usually found the cortical substance intensely red, but without adhesion to the membranes, whilst in chronic cases it is indurated and adherent; but where the insanity has been complicated with paralysis, he has usually found the medullary (fibrous) portion indurated and congested." (Carpenter.)

Dr. Brown-Sequard, in experimenting with guinea-pigs, discovered that after he had injured the spinal cord in a particular manner, he could produce epileptic convulsions by slightly pinching the skin of the animal's face. After the lesion in the spinal cord was healed in these guinea-pigs, the tendency to epilepsy remained, and it was transmitted to their offspring. This experiment was unsuccessful with any other animals except guinea-pigs.

Epilepsy is a disease which affects the centers of the internal senses. Precisely what this disease is due to is not known, probably overstimulation and consequent weakening of some part of the nervous centers. It weakens the memory, and may efface the conscience. It is apt to engender a tendency to be suspicious and distrustful, surly, irascible and indolent. These changes are generally temporary, but sometimes, and especially in children, the moral character is permanently impaired." (See Maudsley.) Acute mania may produce similar effects on the moral nature.

Hemiplegic *paralysis* is usually attributable to some structural disorganization of the nervous tissues of the sensory centers (optic thalami, &c.), produced by hemorrhage, softening, &c. Sometimes, however, it is due to deteriorization, or poisoning of the blood, or its deficiency of nutritive elements. A partial paralysis results from the presence of

lead in the system—lead poisoning. In these cases, and in most cases of epilepsy and hysteria, the sensory ganglia are thought to be chiefly, if not exclusively, involved, because there is not such confusion of ideas as should be expected from a disturbance of the cerebral tissues. Epilepsy, according to Dr. Todd, arises from defective nutrition of certain parts of the brain centers, which causes a gradual disturbance of their polar state. This produces a tension of nervous energy, which periodically becomes too strong for restraint, and discharges itself in the epileptic paroxysm.

Chorea, or St. Vitus dance, is a disease in which the cerebral influence over the movements of certain parts, is much diminished, while the parts are still left subject to the stimulation of the sensory (basal) ganglia. The result is an irregular and ungoverned movement of the muscles of the limbs, trunk or face. These movements do not continue during sleep, and they are apt to be exaggerated by emotions. The disease is usually preceded and accompanied by imperfect nutrition, a depraved state of the blood, and torpor of the system.

Coma is a state in which the sensory ganglia are chiefly, if not exclusively, involved. Their functions are more completely suspended than in sleep, and no impressions are conveyed to them from the outside. The cerebrum does not appear to be involved generally, because there is no confusion of ideas following the comatose state. In hysterical patients sometimes the state of insensibility comes on suddenly, even in the midst of a sentence, which is being uttered. On the return of consciousness the person will go on and finish the sentence as if no interruption had taken place, and in fact he is not conscious that there had been an interruption. Coma is induced by narcotic poisons, the same which in smaller and less intense measure would produce delirium; also by exhaustion and a deficient supply of blood, and by concussion of the brain. In all cases, the cause seems to be due to deficient blood supply. Coma acts like sleep in affording an opportunity for the repair of the brain tissues worn out by excessive mental action, or other injury. There are many cases on record, of protracted sleep lasting for many days and even weeks. Such cases seem to be allied to hysteric coma, rather than to natural sleep. An unusual tendency to ordinary sleep indicates a congested state of the brain, a deficiency of blood, which tends to apoplexy; and it is said that apoplexy has been actually induced by the experimental attempt to protract sleep as long as possible. (Carpenter.)

The total disuse of an organ causes the atrophy of the nerve and brain cells exclusively belonging to it. In fig. 377 is shown a wasted optic nerve consequent upon permanent blindness in the left eye, while the left nerve is nearly normal. In this case the wasting is traceable

across the optic chiasm into the optic "tract" (e). But there are cases in which the injury is communicated to the optic tract on the same side as the atrophied nerve (See fig. 369). The right *side* of each eye is connected with the right side of the brain, and the left of each eye with the left side of the brain.

Hysteria appears to be due to a letting down of some of the nervous elements, probably from prolonged or undue erethism or excitement, so that they no longer enter their influence in the formation of the will.

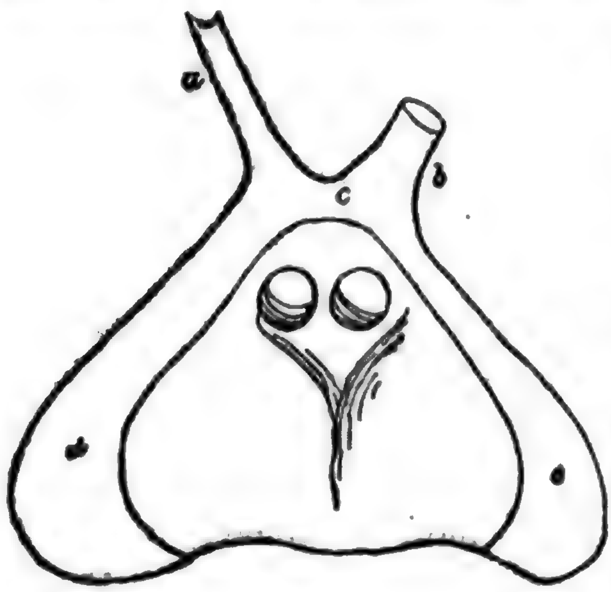

FIG. 377.

FIG. 377.—Diagram of Optic Nerves, showing atrophy following the destruction of an eye. (Owen.)
a.—Atrophied nerve, leading to lost eye.
b.—Nerve leading to the sound eye.
c.—Optic Chiasm.
d.—Optic Tract, more of which is connected with *b* than with *a*.
e.—Optic Tract partly atrophied in connection with *a*. (See fig. 369.)

The elements thus affected to produce hysteria are either some of those which are concerned in the social functions and relations, or are nearly connected with them. The morbid action requires for its stimulus the presence of an audience. To this audience the patient morbidly appeals for sympathy, admiration, &c. To work upon her audience effectually, she will often resort to deception, first perhaps becoming deceived herself. Such patients will feign a great variety of diseases, and pretend to various disabilities which exist only in the imagination. The disease is, or includes, a letting down of the machinery of the moral sensibilities, and is a process of the undoing of some of the results of social evolution. When paralysis, or blindness, or speechlessness is feigned, as is often the case, while there is nothing at all the matter with the nerves of motion, the organs of speech or of sight, the disease and the disability are still as real as if these organs were visibly injured. The seat of the trouble is in those cerebral ganglia which lie between the memory cells of sensation and the nerves of motion; those ganglia which are differentiated after birth and during the educational period of life, and which register those relationships in the environment that are ascertained by those cerebral interactions which make up what is commonly called reflection. They belong to the class of ganglia which are described as being the seat of the *internal senses.* The healthy action of the internal senses is essential to the formation of a properly balanced purposive will. When any of these centers fail, therefore, from inadequate nourishment, it is the will itself which becomes distorted, eccentric, and only half made up. The want of a will is just as effectual a bar to the movement of a muscle as

the paralysis of the nerve would be. Some of the phases of this disease are fickleness, capriciousness, and instability of purpose, which are due to fluctuation in the processes of the nutrition of the ganglia. The ganglia are of fluctuating force, one moment spasmodically vigorous, and the next relapsing into feebleness and inanition. (The remedy for hysteria is work at some outdoor manual toil.)

The decay of muscular vigor is shown in inability to sustain continuous action. In like manner the degree of cerebral force is measured by the vigor of attention. Hemiplegic patients, whose brains are partly disorganized, and patients with dementia, quickly tire of giving attention to a speaker and can sustain a conversation only a short time. Esquirol says, imbeciles and idiots have such very small power of attention, that he often found it impossible to get them to keep their eyes shut long enough to have plaster casts made, although they were as desirous as he. On account of their defective attention their sensory impressions, sight, hearing, feeling, &c., are feeble, defective and inaccurate. The construction of the cerebral organs is founded exclusively upon sensory impressions. The delicacy of tactile impressions depends upon the delicacy and fineness of the skin. The muscular sense corresponds as to delicacy with that of touch, the muscles, considered as organs of sense, corresponding with the skin. The delicacy of the tactual sense is an indication of the delicacy of all the other senses. Persons of coarse skins are dull in their perceptions. Susceptible persons are called thin skinned and vice versa. The delicacy of cerebral processes depend upon the fineness of the sensibilities, that of the skin among the rest, and they often rise or fall together. A case is reported of a young man of good character and intelligent, who having become anesthetic in his skin, suddenly became undisciplined and rebellious to the utmost extent, and gave himself up to the worst tendencies even to the compromising of the peace and honor of his family. When he recovered sensation he also recovered his usual rationality. He had several relapses with the same effect.

The eye is a very important regulator of our movements, which are very uncertain and insecure when deprived of its guidance; and sight forms the basis of an immense number of our internal sense organs. By means of comparing new sight sensations with these standards, we judge of distances, the direction of the movements of objects, their forms, sizes, relative positions, &c. Sight also enters into acquirement of knowledge by reading, by means of works of art, &c. So it is easy to see what a hole would be made in the mind were it deprived of sight. Hearing and the other senses are in the same way essential bases of mental activity and cerebral organ construction. When the senses are at fault, evil effects are sure to be entailed upon the cerebral organs and the mental demonstrations arising from their action.

Bouisson had for a patient a "young man who had become insane in consequence of a double cataract, with incoherence of ideas and complete failure of spontaneity." He performed the operation of couching in both eyes. In a few days sight returned, and in a few weeks his mental condition improved so that he could take care of himself. Another case is reported by Baillarger of a "patient who, if his eyes were closed by another person, even without sleeping, fell into a great disorder of mind. It seemed to him that he was transported through the air and that his limbs were falling off." Another, a woman of 27 would, if her eyes were closed, see all sorts of objects, as fields, animals and houses. "According to Dumont," out of 120 persons who are blind, 37 are affected by intellectual disorders "varying from hypochondria to mania, hallucination and dementia," and not counting with these any who were affected with appreciable lesions of the brain.

The embryo of the Tænia Solium is hatched from an egg taken into the stomach. (See page 190.) From there the embryo wanders through the tissues and finally becomes encysted in some enclosed cavity. "Some have been found in the eyeball, in the lobes of the brain, in the heart or in the muscles. We have lately read an account of the effects produced by one of these wandering worms on a man who died after suffering from a peculiar disturbance of the mind. Two spirits seemed to haunt and speak to him, the one a German the other a Pole. Filthy images were called up before his imagination. At the post mortem examination cysticerci were found to occupy the sella turcica near the commissure of the optic nerves. One of these was alive, the others were calcified. Two others in a similar condition occupied a lobe of the brain." (P. J. Van Beneden, 218.)

"Kuchenmeister, who collected 88 cases of cysticercus of the brain, found the cysts 49 times in the membranes, 6 of which were on the dura mater, 11 on the arachnoid, 23 on the pia mater, 9 on the choroid plexus. Fifty-nine on the surface of the cerebrum, 41 in the cortical substance, 19 in the white substance, 18 in the ventricles and aqueduct, 17 in the corpora striata and anterior commissure, 15 in the optic thalami and gray commissure, 4 in the corpora quadrigemina and pineal gland, 2 in the trigona olfactoria, corpus callosum and medulla oblongata, one in the olivary body, and 18 in the cerebellum. In the above, 18 per cent. were without any symptoms, in 6 they were only trifling, in 5 epilepsy alone was present, in 4 epilepsy with mental debility, in 15 epilepsy with paralytic symptoms, in 24 insanity without epilepsy, of which 7 were without motor or sensory disturbances, 17 had lameness, cramps, hemiplegia, paralysis and muscular twitchings, while out of all only 24 had epilepsy." [1]

[1] From a paper by Dr. R. Harvey Reed, of New Orleans.

CHAPTER LXX.

THE WILL.

Dr. Sam. Johnson said, "We *feel* that our will is *free*, and that's the end on't." When a little dog sees his reflection in a glass for the first time, he feels very sure it is another little dog. Our sensations, it is true, are all we have to go by, and yet a single unverified sensation may fool us badly. Before it is entitled to full credence and influence, it must be tried by its peers in the shape of other sensations. If they *all* agree, we are bound to accept the verdict. They are *not* all agreed that the will is free, as we shall see.

Carpenter, too, who has many excellent suggestions on this subject, which I shall freely quote, nevertheless gives himself away by the remarkable confession "That the scientific investigation of the nature and source of the will "has seemed to lead to results which are inconsistent with our intuitive conviction of freedom as well as with our scarcely less intuitive notion of moral responsibility." That "scientific investigation" leads to such results, ought, it would seem, to cause some distrust of these subjective or supposed "intuitive" notions. That it often does not, is evidence of the singular perseverance of habit in thought. In regard to the *freedom* of the *will*, what our conviction really amounts to, is, that when the will is formed for the movement of a muscle, such movement will take place. From the observed uniformity of the result we ought rather to argue its necessity than its freedom.

One says, "See! I can move my hand and bring it to rest, as I please." How? "By simply willing to do it." The language shows the necessity of the hand to move when "I please," and also indicates the will itself as following the "I please," as a term in a series of three, I please, will, and muscle movement. The position of the will in this series indicates its contingent and conditional nature. If the pleasure is different, the will is different. We are apt to confound the will and the pleasure as one, but it is easy to show that in reality they are two, and that the pleasure must precede the will, and if there is no pleasure no will is formed. Pleasure is simply a general name for a class of sensations, and sensations are the immediate or remote result of sensory stimulations. The will is therefore under the domination of sensory stimulations, and these in turn depend upon the environment.

Will merely determines the result, but is not concerned in the selection and combination of the muscular movements necessary to bring this result about. Thus, a child can raise his eyelids (if he have a motive to do so) but he cannot tell whether in so doing he contracts one

muscle or a dozen. In fact, he does not will to contract a muscle at all, and does not know that the thing he does will to do, involves the contraction of a muscle. If he will at the same time to move a leg, there is nothing in his consciousness to show that a different set of muscles have to be contracted in this case; and although the action involves a much more complicated adjustment and co-operation of muscular contraction, involving several muscles instead of one, he knows nothing of this, and it is as easy to will one as the other. If we fix the eyes upon a moving object, as a running horse for example, the eyes will roll in their orbits so as to keep the image upon the retina. All we have willed to do in this case is to see the horse. We are quite unconscious of the slow and uniform contraction of the rectus externus of one eye, and the rectus internus occuli of the other, by which our will is carried out. In fact, these muscles perform the operation as well for a monkey or an Indian, who does not know of their existence, as for the anatomist, who is competent to address them by their highly distinguished names.

It is the same in regard to the production of vocal tones, "for we cannot raise or depress the larynx as a whole, nor move the thyroid cartilage upon the cricoid, nor approximate the arytenoid cartilages, nor extend or relax the vocal ligaments by simply willing to do so, however strongly." (Carpenter.) What we do will to do is to produce a given tone. A *conception* of this given tone is in the brain first, and the will is, to have this conception vocalized. The vocalization consists in the reproduction of a series of muscular contractions in the same order in which they have been produced before (according to a cortical memory), or in the order in which they have been produced before, modified by a new stimulus from the environment; for example, the hearing of new sounds, the new stimuli mingling their forces with the memories of the old stimuli, and thus producing a new *conception*. This "conception" consists, therefore, of a bundle of either potential or active stimuli, the constituent elements of which are each singly competent to liberate upon some muscle the nervous energy necessary for its contraction. Whether it does so liberate it depends on further motive stimuli from the environment. Thus, a man may have the conception of a song, but he will not sing it unless he have an appreciative audience that wishes it. The real ultimate motive power in the creation of a will for the production of vocal sounds, therefore, is in the sounds produced in the environment and projected upon the sense organs, and conveyed thence by the nerves to the sensory ganglia, and from them to the vocal organs, producing an outcry, or they may be transmitted to the cortex of the cerebrum, registering as a memory to occupy a potential position, ready to become active upon a further reinforcement of stimuli. When this further reinforcement does take place, the aggregate compound stimulus,

as then constituted, passes down the efferent nerves and is distributed toward the same muscles that would have been affected if the same stimulus had gone directly from the sensory ganglia to the muscles without first going to the cerebrum. In but few cases, however, would the stimulus returning from the cerebrum be as simple, or in any way quite similar to the elements which compose it, although they all came from the environment originally. No doubt all our vocalization, including language, is the reflection through our organs, of sounds projected upon us from the environment. The howling of dogs when a bell rings, is an indication of the original tendency of sound to produce vocalization. (See on Language.)

Muscle moving is to be attributed to the external stimuli, therefore, whether directly by reflex action or indirectly through the cerebrum, the will constituting merely one term of the series in the indirect stimulation. The apparatus through which the so-called voluntary actions are performed, are precisely those through which the automatic actions are performed, the only difference between the two being not in the action itself, but in the origin of its exciting cause. In the automatic actions the movement may be immediate, and result directly from the simple, efficient, incoming stimulus. In the voluntary actions, the movement is not immediate, but is the result of the incoming stimuli after time has been consumed by them in mutual limitations and modifications.

Some actions that are ordinarily automatic may be performed voluntarily; for example, coughing, winking, breathing, and the like. We may do these things under the stimulus of will, but when we do, they are performed by the same automatic machinery as when they are performed involuntarily. The will in the case of voluntary coughing, for example, is the stimulating agent in the place of the local irritation in the throat, which ordinarily starts the automatic action. There is another class of stimuli which come also from the cerebrum but which are not voluntary. These are the ideo-motor stimuli, or the stimulation by ideas. The paroxysms in hydrophobia are brought on by the sight of water, but they may also be excited merely by mentioning water by name; the name exciting the idea. So vomiting has been excited by the remembrance of a nauseous object which has provoked it before, and yawning by seeing a picture of yawners. Carpenter mentions a case of sea-sickness brought on by the sight of a vessel tossed about at sea, which recalled a former experience of sea-sickness in the subject.

On the other hand, there are many actions which beginning as voluntary become, through habit, automatic. The greater part of our muscular movements come under this head. In infancy, these are learned slowly and with care and attention, but after awhile they become easy, and finally they do themselves. In walking we simply will to start,

but the will has not only not the least authority over the methods of muscular contraction, but we do not commonly even take cognizance of the movement of limbs which results from these contractions. That is, through habit the actions become more and more frictionless, and at the same rate become automatic and unconscious. In ordinary walking, the stimulus is the muscular sense, modified by the visual and perhaps other senses. Every step taken after the start is made, liberates a stimulus for another step. If the cerebral stimuli are not on the alert to interfere at the proper time with this automatic, self-perpetuating stimulus of the muscular sense, it will carry the subject beyond the intended stopping place, a thing common in the experience of everyone. If nothing else interferes, however, the muscular sense will itself finally be modified by the fatigue or exhaustion of the muscles, and this will become a new automatic interfering stimulation.

We are totally unconscious of the formation of a will before it is formed; that is, we do not know beforehand that we will have such a will, and we are often unconscious of the process through which it is derived. But we are conscious very often, though not always, of the execution of the muscular expression of the will; that is, of the transformation of the nervous energy of the brain centers into mechanical energy through muscle contraction. As long as we are in health there is nothing inside of us to interpose between the formation of the will and the movement of the muscle, hence the conviction of the freedom of the will to execute its conclusions. In other words, the first consciousness we have of any will is *after* it is formed, and during its execution. We see the cause constantly and uniformly followed by its effect. We seldom trace the causes of the cause, and do not become conscious that there are any, except after a process of reasoning. If we are not enlightened by this process, the will often appears to *our consciousness* a *first cause.* And so it has sometimes been reckoned by metaphysicians.

"Although certain states of mind have a remarkable influence on organic functions, no change in their usual course can be determined by the direct influence of the will." The only sensible effect which the strongest effort of the will can produce, is the concentration of attention in the direction of muscle contraction, or cerebral action.

It is essential to volitional action that a distinct idea should exist of the object to be attained, also a belief of the possibility of attaining it by the means employed. And other things being equal, the force of the exertion is in proportion to the concentration of the attention to the work. Emotional excitement may either intensify or paralyze the volitional power. Dominant ideas are competent to modify the volitional force the same way. A person in the hypnotic state, one of Mr. Braid's

subjects, was known to swing a 28 lb. weight around his head by his little finger. His muscular development was very deficient and in his ordinary state he shrank from the least exertion. His power in this case came from the concentration of all his nervous energy upon the effort, which in this state can be done not because, as some say, the will is set aside [1] and the man is governed by the idea suggested by the "professor," but because that part of the brain is dull and passive, which in its waking state would supply such elements of doubt and distraction as would counteract and weaken the idea suggested by the professor. So that the resulting will formed of these mutually cancelling and discordant elements is, in the waking state, far weaker than in that of artificial somnambulism. When this subject was assured by the professor that he was physically incompetent to lift a handkerchief, he failed to do it after apparently strenuous efforts. Here the only active idea the man had on the subject was unfavorable to the formation of an efficient volition, so it was not formed. When a person is under the influence of some overpowering emotion which absorbs all his attention he is in a state somewhat analogous to that of the hypnotic subject who is engrossed by a single idea. "An old cook maid tottering with age, having heard an alarm of fire, seized an enormous box containing her whole property, and ran down stairs with it as easily as she could have carried a dish of meat. After the fire had been extinguished she could not lift the box a hairs-breadth from the ground and it required two men to convey it up stairs again." The principle illustrated in this case is precisely the same as that in the case of Mr. Braid's subject mentioned above. But nobody will pretend the woman's will was set aside. On the contrary it was astonishingly strengthened by an unusual stimulus. When we have a doubt regarding our ability to perform something, it may be, and often is, modified by the expression of the opinions of other people in the nature of suggestions which go to form strengthening or detracting elements of our will.

Again, a desire may fail to become an operative will. This happens when the subject insanely or hysterically loses his belief in his ability to do what he desires. He is like the hypnotic subject who thought he could not lift a handkerchief and therefore could not.

Carpenter cites the case of a man who could not do so simple a thing as take off his coat when he wanted to go to bed, although he greatly desired to do so, and had all his faculties about him except an efficient will to move the necessary muscles. Once he could not for half an hour pick up a glass of water he had ordered and wished to take.

In another case the inefficiency of the will was limited to the man's going into or past vacant spaces. It took some minutes to pass through

[1] Carpenter takes this ground.

a doorway. Crossing a street was very difficult, and passing an unbuilt space along the street an impossibility. These parties felt as if their will was thwarted and held in possession by some other person.

We are liable to fall into the same error concerning the original jurisdiction of the will in the matter of directing the action of the brain as in the matter of moving the muscles. We talk about concentrating our minds upon a distasteful subject by a powerful effort of the will, &c. We say the will can forcibly "detach attention from the most attractive subjects and direct it to others less attractive." Obviously from what has gone before, the *will* can do nothing of the sort. Neither can anything else do it.

We are not all made alike, and consequently the effects which the will is competent to produce are different in different people. As a rule, we say the will has power to cause the contraction of the muscles. But in some people this power is of far greater force than in others. We possess some muscles which nobody now has the power to contract, and others which some men can contract and other men cannot. (See chapter 5.) We likewise say we have the power to direct our *attention* in some particular direction; but this power, too, is possessed in very unequal degree by different persons. This is the power to direct the flow of blood to one or another of the cerebral organs, and depends upon the same sort of physiological basis as the concentration of force in muscle action. In fact, the concentration of energy in voluntary muscle action must be preceded by concentration of attention, and this, as the illustrations above cited show, depends upon the intensity of the motives, and their singleness, or freedom from opposing motives. The concentration of attention consists in the singling out of a special arterial branch or twig, and stimulating in it an increased supply of blood, by which an increased action is stimulated in the organ, or patch of the cerebral cortex, which depends for its sustenance upon such twig. Such concentration necessarily involves, and to a certain extent depends upon, deprivation of those organs not included in the scope of the stimulation; so that attention includes the increased activity of one organ or set of organs, accompanied by a decreased activity of the others.

The course by which the nervous stimulus reaches the blood-vessels, appears to be by way of the brain organ itself, which is to receive the benefit. The stimulus, which is primarily a sensation from the environment, reaches its appropriate correspondent organ, and, if strong, sends on from it into its supporting blood-vessels a stimulation which liberates a larger supply to the organ. The stimulation of the cerebral organ is followed so rapidly by that of the arterial vessels upon which it depends, that their action appears simultaneous, though it is doubtless rapidly reciprocal. In those muscular actions which are performed un-

consciously, and are denominated reflex, the stimulation, after passing the sensory centers, goes directly to the muscles instead of going to the cortical organs of the cerebrum. The first movement of the muscle, under such stimulation, liberates a stimulus upon its co-operating blood-vessels. This is instantly followed by an increase in the blood supply to such muscle, which in turn promotes the increased energy of the muscle for further action. So that there is the same correspondence and mutuality between the muscle and its blood-vessel as between the cerebral organ and its blood-vessel, and both systems are equally dependent upon the advent of a stimulus from the environment by way of the sensory centers. That which goes to the muscles without exciting the cerebral organs, produces reflex actions. Such actions follow the habit to which the part moving is accustomed. If a threatening gesture is made near the eye, it will wink without the intervention of the will. Although the gesture being seen, the stimulus is carried up to the cerebral organs from the sense organ at the same instant that the motor stimulus goes back to the muscle of the eyelid. The reflex muscle action is as rapid in this case as the cerebral action, and the lid has been snapped shut at the same instant that the cerebral organ has been affected, and given rise to a sensation of the gesture. We recognize that the cerebral or memory organs are not involved in the case by describing such muscular action as involuntary. But if the stimulus is not too sudden and powerful, the action by way of the cerebral organ has time to interfere and modify the motion of the muscle. Thus, if I walk along the road and meet with an obstruction, I am conscious that cerebral action determines in what way I shall avoid it. The secretory glands, too, like the muscles, as shown elsewhere, are subject to stimulations either independently or in connection with cerebral organs.

Whenever the muscular action is modified by stimuli deflected from cortical cerebral organs, we call it voluntary, and in like manner and for the same reason, whenever attention is directed in any particular way by the deflection of stimuli from other cortical organs, we call that voluntary attention. (See page 498.)

We thus perceive that no new or exceptional physiological principles are involved in the mechanism of attention, but the same sort of sensory stimulation arouses attention which arouses reflex muscular action, and does it by the same process. The will, therefore, both in muscle contraction and in the stimulation of organs of the cortex, in arousing attention, is a direct or indirect outcome of a sensory stimulus, and would not exist without it. It is shown in chapter 73 that abstraction, artificial somnambulism, &c., are simply more intense and exclusive states of attention. It is obviously inconsistent, therefore, to say that the will is subverted and set aside by a suggested idea or sensory stimu-

lation in the case of hypnotism, when it is not in the case of ordinary attention.

Common attention as well as hypnotism is a condition in which cerebral activity is concentrated upon one organ, though to a less intense degree because less exclusively. If the state of things is not brought about by the will in the case of hypnotism, it cannot be thus brought about in the case of attention. And if it be held that when a man is in the hypnotic state his will is set aside and his further actions are not controlled by the will, but by a dominant idea or by the suggestions of the operator, then we must hold that when the attention of a man has been enlisted, his further thoughts in that direction, or actions arising from them, are no longer subject to his will, but that he is moved by dominant ideas or sensorial suggestions. The mode of action is identical in the two cases. Yet it must be maintained that if a man is ever under the domination of motives which come from without it is when he is hypnotized, and if his actions are ever governed by a will, and as free a one as a will ever gets to be, it is when attention is purposely concentrated upon some line of thought or action. It logically and necessarily follows that control by a will is government by dominant ideas. In the case of hypnotism the dominant idea is so conspicuous that we see it to be the real motive power behind the will. In ordinary attention the dominant idea is more or less out of sight.

The will then, is one link in the chain of stimuli, which beginning as a mode of energy in the evironment, ends, so far as we are concerned, as a muscle contraction or a cerebral agitation. It is that link which in a special manner arouses consciousness and perception of its action and its relation to the final action of muscle following it. It is indeed a cause, but not a first cause. It is the last one of which we are conscious of a train preceding and leading up to motor results. We are often conscious of the existence of other links in this chain of causes, or rather we are conscious, after the fact, that such and such ideas have formed a final stimulus sufficient and appropriate to move muscles. We are conscious of the presence of that stimulus and of its relation as cause to the motor muscle action. We call it will. We are not conscious, however, of the manner in which it becomes cause, or rather of the manner in which a motor nervous current and a muscle contraction become effect.

Next, we are to remember that the vibratory stimulus which we thus trace, is not the driving power by which all these cerebral changes are made and the muscle of the limb finally moved. As in certain chemical combinations which are promoted by sunlight, the sunlight alone is not the motive force, so in these mechanical changes in organic tissue, the sunlight furnishes a disturbing force by which the greater energies generated in the blood are started into activity. As observed in chapter 51,

the muscle force when liberated is probably from six to ten times as great as the cerebral energy which touches it off. And so for the same reason we may infer that the cerebral action, after attention is aroused, is of far greater energy than the stimulus from the environment which sufficed to arouse the attention.

We are not conscious of willing to contract any *muscle*. We move our limbs long before we know that such things as muscles exist. There is a disappearance of the will after it is formed, and in disappearing it is succeeded by a nervous motor current which stimulates the contraction of some muscles. But of this action we are not conscious. We do not know what muscle is being contracted from any subjective sensation we may have of it. If we find out, we do it objectively, through the external senses, by experimental inquiry and by analogical inference. When the nervous stimulation disappears in muscle contraction, the result appears to us in the new position of the limb which has been moved. Our knowledge of this, too, is gained objectively through the muscular sense or the optical sense; we feel it or see it in its new position.

We thus trace the stimulating energy from the external sense organs through the afferent nerves into the internal sense organs, and through these into the motorial centers, thence through the efferent nerves to the limbs. Our consciousness, such as it is, of each step taken in this chain of sequences, is in each and every case subsequent to the fact. We become aware of each stage of the progress of the stimulation after it is over, not before; that is to say, of each of the stages of which we ever become aware, for of some of them we get no sensation or other direct knowledge.

(1) We have no sensation of the first impact of the stimulus upon the sense organ.

(2) We have no sensation of the passage of the stimulus up the afferent nerve to the sensory ganglia or to the cortical organs of the cerebrum. (It divides and goes to both destinations, fig. 354.)

(3) The agitation of the cortical organ constitutes or involves sensation, and here we get the first sensation of the fact that such a stimulus has struck us. We call this an objective sensation. The stimulus, upon reaching the cortical organs, disturbs the equilibrium of the polar tensions there, and sets up a variety of movements, working toward a readjustment which shall include the new stimulation.

(4) We may get sensations of these processes, and we name them variously, as perception, comparison, discrimination, reasoning, emotion; and following these, desire, determination, and, lastly, will.

(5) After the formation of a will, so much of our stimulus as has been engaged in it, disappears with the will, and with it disappears sensation of its subsequent performance which is now motorial and effer-

ent. It first takes the form of a nervous current down the efferent nerves, and lastly, ends in a stimulation of muscle contraction.

In tracing the stimulus from the sense organ to the muscle, as above, I have, for the sake of simplicity, mentioned it as *one* stimulus impelled from one organ to another. The case is really much more complicated. Before the stimulus reaches us from the outside, it consists of the movement of some sort of matter. If it is a sight stimulus, it is the vibratory movement of the ether in a particular tone. When this reaches the retina it ceases as such vibrations and is succeeded by the motion of a different sort of matter; viz., a molecular agitation of the rods and cones of the retina. This agitation communicates motion of another sort to the optic nerve. This motion, which is supposed to be a molecular tremor of the material in the nerve, is rapidly propagated along it from the retina to the brain, and is called a nervous current. In the brain cells with which it connects, the tremor of the nerve is exhausted in setting up their molecular agitation which is peculiar to themselves (a color perhaps), and depends upon their form and molecular constitution and polarity. From cell to cell, through many of the internal sense organs, the motion reverberates, now a current as it progressively thrills the molecules of the connecting nerve fibres, and now setting up polar tension in the cells and re-arranging their molecules. I take it, the action is not precisely the same in any two cells, but each one vibrates in the manner necessarily accompanying its peculiar structure and polarity, and consequently arouses a different sensation of its agitation. Finally, as a result of all these cerebral interactions, an agitation reaches and propagates itself along a motor nerve, once more a current. All these organs move in a different manner from the rest, but the motion of each is started by the motion of that next preceding it. We see in this transfer of motion from one body to another in the brain cells, merely an example and illustration of the mechanical transfer of energy treated of in chapter 35. Such appearance of energy anywhere must be by transfer. It cannot, without contravention of the law of the conservation of forces, be supposed to come in any other way, and cannot, in the nature of things, be supposed to originate from nothing.

Maudsley remarks that "a new organism is the product of precedent organisms, and of the external conditions of the medium, but it is neither the precedent organism nor the external conditions; nor is it merely the arithmetical sum or mechanical compound of them; it is a new product with properties of its own, distinctly autonomous." He then applies this conception to the will. He says, "motives are necessary antecedents of will, but assuredly will is not motive, nor is it simply the sum of the foregoing motives; it is a new product, the outcome of antecedents

certainly, but autonomous." It possesses *more*, he says, than is contained in its antecedents.

This sort of comparison will not do. We might as well try to compare a ray of light with a pound of iron. It might do if the will were an organ like a liver or a gizzard. But it is easy to prove that the will is a mode of motion and not a thing. The admission that "motives are necessary antecedents of will" concedes that point, for while motives, that is motions, are the necessary antecedents of motions, they are not the antecedents of things. If, therefore, muscle moving, a mode of mechanical motion, depends upon previous mechanical motion, and if what it depends on is the will, it follows that the will is mechanical motion. If we look for the motives which go to make up the will, we find them to be derived from unmistakable modes of mechanical motion in the environment, as light, sound, touch, &c., which give immediate rise to afferent nervous currents. We have no warrant to justify a supposition that the intermediate terms of action whatever they are, which lie between these initial forms of molecular motion, and final forms of the same sort of molecular motion, are anything else than equivalent forms of motion. If we should allow a stream of pure water to flow into a barrel by the bung-hole, and then upon tapping it at the spigot should get nothing but molasses, we would have a right to conclude that some internal works transformed water into molasses; but if we should get nothing but pure water by the spigot we should not conclude that the water was turned into molasses upon entering the barrel and turned back into water again upon leaving it.

Neither have we any reason or right to suppose that the molecular motion which we plainly trace to its entrance into the brain case is thereupon lost from the domain of physics. If we never saw any motor expression come from it, we would say it was dissipated as heat, which is still, however, a form of molecular motion. Such a result happens when we speak to a man in a sound sleep and get no answer. But when we find a motor nervous current coming out of the skull, which is evidently a sequel to one we detected going into it and is its physical counterpart, we conclude that these two are connected by currents just like them or their equivalents. If a boy dodges a snowball, it is because he sees it, or at any rate if he did not see it he would not dodge it. There is no reason to suppose that the sight stimulus which is a form of physical energy mingles with an *immaterial* stimulus or stimulates an "immaterial substance," whatever that is, and that the subsequent physical stimulation which goes down the efferent nerve and causes a "ducking" of the head, is got by the reconversion of the force of this immaterial substance into physical energy. We know there must be physical energy in some form all the way through. Every force is made up by the com-

bination of antecedent forces and is exactly equal to the amount of those forces consumed in its make up.

The will then is a mode of the motion of brain cells, or their materials, communicated to them by antecedent motion of others. It is the resultant of these antecedent motions and in force cannot possibly exceed the sum of them, but it may fall short of that sum because if there is inharmony or opposition between them a part of this force may be wasted in heat, and the result be a weak will, or irresolution as we call it. A match may set fire to a powder magazine, but it does not represent the force of the explosion. So the will may liberate a force much greater than itself; and this circumstance may have led to the idea that it is greater than its antecedent elements.

The will being a motion of matter, and not a thing or commodity, it cannot be made up into measurable and ponderable parcels and kept in stock. The governing supply must be made up every instant for that instant. Resolutions made yesterday of actions to be performed to-day are of no force, and will cut no figure in to-day's action, unless the conditions prevailing to-day are still such as to prompt such a conclusion of the will. The ceaseless activity of the nervous currents compels a re-adjustment of conclusions every moment. Even after the hand is raised to strike, a new adjustment of the will may arrest the blow, or divert its delivery to another object.

The will is made up at different times under different circumstances, and thus results from a variety of motives. Sometimes it results from a sudden and violent impulse, in which case only one cerebral organ perhaps is involved in the modification of the sensory stimulus before it is allowed to influence motor action. At other times the action is deliberate, and the stimulus has time to agitate and be reflected from several cerebral organs before final motor action. We say of such case that the action was "well considered," or that the person had "control of himself."

Some of our actions we call "instinctive," or habitual. These are a class of actions which have been performed so many times by our ancestors or ourselves, that under proper stimulation they are performed without hesitation or keen consciousness of their performance. But the most of our voluntary actions are the result of stimuli reflected from the various cerebral organs of memory, almost always including some of those of an emotional nature, and registering memories of pleasure or pain. Certainly the great majority of our deliberate volitions are colored by reflections from these organs. The few which are not, will probably all be found in the classes above mentioned, as impulsive, habitual, or quasi instinctive. All of them are to be regarded as selfish volitions, since they are formed under the influence of vibrations

reflected from organs belonging to the self as distinguished from those of another, and because these vibrations are necessarily in harmony with the fundamental vibrations, or tone of the organs from which they are reflected. If I were to stand in front of a brick wall and sing the letter G in its proper musical pitch, the echo would return the sound just as I made it, with the peculiarities given it by my vocal organs. But if I make the same sound in the presence of a piano, a G string of the instrument will respond and give back the sound in corresponding pitch, but it will be a piano tone, and not a vocal tone. So the vibrations which emanate from the cerebral organ are the vibrations of *that* organ, and represent *its* peculiarities, regardless of the source of the impact which set it going.

Our feelings are our own, and refer to ourselves, regardless of the sympathetic note in the environment which sets up the emotion. If two pianos are in one room, and the G of one be sounded, the response made by the other will still be its own, although very similar to the sound of the first. So the very close sympathy of our emotions with their cause, has often deceived us to imagine them to be unselfish. That we have organs so closely in sympathy with those of other men, is due to the identity of environment surrounding them and us, as pointed out in chapter 68.

If the will is made up of antecedent stimuli and reverberations of stimuli from internal sense organs, of a part of which we are usually unconscious, and of the whole of which we *may* be unconscious, as shown in chapter 75, it may be asked how pleasure and pain can enter into its composition *unconsciously*, since the very terms seem to imply consciousness; and since, moreover, the stimulus of pleasure or pain in order to influence will, must exist before it. It is obvious, upon a moment's reflection, that it is not the first sensation of pleasure or pain that influences will, but the memory of such sensation in the past. If a child deliberately puts its fingers on the hot stove, it is because it has no active memory of the perception of the connection between stove and pain. But its present experience will instantly establish a cerebral differentiation, the reflection from which will give the perception of the painful relation between stove and hand, and cause the withdrawal of the hand. If such perception were not established, the hand would stay there and be destroyed; and this might actually happen to a very young child, or to an idiotic, insane, or paralyzed person. The condition of the avoidance of pain is a perception of a cause in relation with it. Now a perception of relations cannot exist in our brain till after the sensations of the related things have been experienced. So it follows that we are not influenced by the original sensations of pain, but by the recollections of them.

We do not avoid any pain which we actually suffer, but that which threatens us in the future. It is through the reactions of the memory organs of painful sensations, that the will is formed to restrain the actions which lead to their repetition. Since, then, it is not the sensation but the memory which enters into the formation of the emotional volition, this sort of volition is upon the same footing as the intellectual and ideational volitions. All depend upon the reactions of stimuli upon cortical organs, any of which reactions may take place in unconsciousness, as is shown in chapter 75. Although we speak of emotional, intellectual and ideational states, there are no definite boundary lines between them. They grade into each other, and are frequently all involved together.

Therefore, we find all sorts of cerebral reactions going on in unconsciousness, including those relating to the avoidance of pain, an example of which is seen in the avoidance of danger by somnambulists. The actions we perform in unconsciousness, when they are subject to cerebral modifications and influences, are necessarily preceded by that same term of molecular cerebral motion which is immediately antecedent to the motorial or efferent nervous current, the same term which, when it is manifested during consciousness, we call will. There is no impropriety, when this term is active during unconsciousness, in designating it as unconscious will.

It is necessary to bear in mind the distinction between the will as a term in the chain of cerebral stimulation, which culminates in muscular action, and the *sensation* of the action of that term. I have used the word *will* to signify the effectual action, and have no single word to express the *sensation* of it which may or may not be aroused. Commonly the word will has been used apparently to cover both, which leads to confusion. The distinction between the *impressions* made by external stimuli upon our sense organs, and the *sensations* of those *impressions* aroused in the sensory cells, was recognized by Carpenter. The very same sort of difference exists between the impressions made upon the cerebral organs, or *internal* sense organs, and their sensations, and should be distinguished. All of the processes which go on in these organs, it is demonstrated, may go on in unconsciousness; that is, may happen without arousing their corresponding sensations. So that we have unconscious activities in *perception*, *ideation and will.*

It has been shown that the performance of muscular actions requires the co-operation of a *guiding sense.* That is, while muscular contractions could take place in simple obedience to reflex stimulation, they could not take place intelligently under stimulus from the internal senses and the will, without the continued presence of a guiding sensation.

"In learning to dance," says Hartley, "the scholar desires to look at

his feet and legs in order to judge by seeing when they are in a proper position. By degrees he learns to judge of this by feeling." So it is the impression of a sense, first the visual, and after that the muscular sense which supplies at each moment the guide for the next movement. After long practice the "guiding sensation" ceases to become a sensation and sinks to a sub-conscious impression; and yet it still is sufficient to guide the consecutive actions in the train to which it belongs, and when the dancer takes the steps without thought or care, the action has become instinctive.

Now it may be shown that the activities of the purely cerebral states, which may not immediately culminate in muscular contractions, and which are denominated intellectual, emotional and ideational, likewise depend upon guiding sensations, the sensations, however, coming from stimulations of the cerebral organs or internal senses, instead of the external sense organs. This may be seen by analyzing the process by which a dormant memory is revived. First, there must be a disturbing stimulus from the environment, which so connects itself with some one of our cerebral emotional organs as to produce a *motive* or purpose. A motive may be defined to be an incomplete or inharmonious cerebral state, and being so, it is a more or less unpleasant state and demands or inaugurates further activities amongst the cerebral organs, and will continue to do so as long as it is sufficiently strong, or until the inharmonious conditions are eliminated; that is, until the motive is satisfied. It is supposed in the example proposed, that the revived activities of a certain memory are fitted to harmonize the elements and satisfy the motive. The stimulation of the first organ, as above, produces in it an action which overflows toward another, which its tone is competent to excite, but which may perhaps not be the memory wanted, but something like it or something related to it. This in turn arouses another and another, until finally, perhaps, the one which entirely satisfies the motive is reached.

That such is really the process of recollection, may be proved by an effort to recall a forgotten air or a forgotten verse. We repeat what we do recollect of it, that is, restimulate so many of our organs of it as readily respond to the stimulation; and if that does not have the desired effect, we do it again, repeatedly. We instinctively expect that somehow what we do remember will restore to us what we have forgotten, and it usually does. If we cannot recall it in this way, after the exhaustion of the effort in this direction, the motive, if still sufficient to compel attention, will send the stimulation in the direction of the next least resistance. It may occur to us that some easily accessible person is acquainted with what we want to find out, or we remember the book we got it from, &c., and thus, like water dammed up in one direction, the persistent stimulus finds an outlet in another.

Now this action of various organs thus brought into co-operation to a definite end, each step or instalment of which action changes the relationship of our consciousness to the recollection required, is in the nature of a series of guiding sensations. If a man has an appointment to be at 301 Hennepin Ave. at 3 p. m., in order to keep it he must have the guidance of certain sensations. As he walks, each step taken supplies, by the activity of his muscular sense, the data for the next. If his muscular sense were paralyzed, the second step would not be taken, unless the visual sense should become a substitute for it, and if that, too, were paralyzed, the journey would immediately terminate, regardless of the fact that his motor apparatus might still be in good order. We do not realize, without special attention, how dependent our physical movements are every moment upon these guiding sensory stimulations. When the man has finished his walk, every step of it will have been at least temporarily registered in motions of his nervous tissues, the whole constituting a series of motor acts alternating with sensory stimulations like the endless thread of a chain-stitch seam. The thread cannot make a new efferent excursion till it returns from the last one. At any point on the journey if this thread could be traced and the stitches counted, the position of the man with relation to his starting point could be ascertained, and he could recover his starting point by retracing his steps. That is just what is done in the processes of recollection requiring effort. The organ of each separate step is restimulated by the passage to it of the stimulus from its next neighbor. As each restimulated organ reflects its agitation back to the organ representing the motive, if it fails to satisfy it, it becomes the basis and guide of the next forward movement of stimulation, and so on till one is reached which completes the motive. Just as, after we have walked toward our destination for a length of time, at the end of each step we are still prepared to take another, conscious that each step, while it is not the one which is to complete the journey, is forming a necessary preparation for a final one that will.

In the foregoing I may not have correctly indicated the details of the physiological processes, since our knowledge is in part inferential, but I have, without doubt, pointed out the principles upon which all purposive cerebral action proceeds; for, as we shall see, it is all based upon memory. The performance of a purpose to reason, to compose a poem, or to solve a problem, is carried out upon the same general principles as those which govern the recovery of a memory. Indeed, all such action is nothing more than the recovery of memories.

The processes or motives which enter into the formation of the will, are, of necessity, automatic, and they are often unconscious. To suppose otherwise is to assume that every will is the offspring of a will that

went before it. But, as before observed, we are never conscious in advance that our will is *to be* so and so, but after the processes have had their action, and the will is formed, we may (or may not) become conscious of the result. If the processes are sufficiently slow in their action, we may become aware of their presence, and influence seriatim and separately. In each pause of this action, these elements of motion may begin to crystallize into a will, which, however, before there is time for it to act, may be set aside or superseded through the further action of the antecedent motives. Our sensation during this sort of performance we express by saying we "*have half a mind*" to do so and so. *After* it is all over, and definite results are reached, we say "our mind is made up," and we *have* such a "will," "intention," "purpose," &c. If the movement of the antecedent stimulus is rapid and violent, the sensation of the result may be scarcely in advance of the motor action set up by the will; or it may be simultaneous with it, the discharge down the efferent nerves taking place at the same instant that the stimulation arouses the sensory function of the cells. Or the energy of the stimulus may be so great as, by its violence, to overstimulate and stun the function of sensation, so that we are not conscious of any will in the matter, and only get a knowledge of our motor act after its accomplishment, through the external sense organs, just as any other spectator would.

Where the will appears to be vacillating and changeable, there are several causes, one of which is no doubt a sluggish temperament, the inertia of the ganglion and cortical cells, and their slowness in being moved by and transmitting moderate stimuli. Instead of the stimuli acting in rapid succession, each one getting in its work on the problem before motor action has time to flow from it, each stimulus is liberated upon the work at a perceptible interval after the effect of those before it is completed. The consequence is, that a motor action is started after the effect of each stimulus, and before it can be consumated the new motive intervenes to change the action, or, if it be completed, to undo it. A person with such a brain is said to lack decision of character. Where the cells are, from temperament or habit, pliant and responsive, if a new motive unlocks the latent stimuli in the brain, they rapidly evolve a balance of forces which includes all the stimuli present, so that the result once reached is not disturbed except by new and fresh stimuli from the external environment. Such a brain is marked by decision, especially if not a comprehensive one, or in possession of many stimuli bearing on the question in hand.

The brain which, under moderate stimulation, appears weak and undecided, may, however, under single and powerful stimulation, exhibit sufficient decision and force. It is evident that if we are assailed by

contrary motives which are nearly balanced, the decision will not be very positive in either direction, and may be reversed more than once before motor action supervenes to reinforce and finally fix the decision. As long as *attention* is concentrated upon one motive, it may cause a determination of the will in a corresponding direction, but as soon as such a will is formed, and attention is no longer monopolized by the motive out of which it grew, unless it be of a nature which proceeds to instant execution, the opposing motive engrosses attention and forms an opposing will.

Decision of character depends further on the directness with which the stimuli move from the stimulating agency to the part of the brain to be moved. If the stimulus affects too many parts, they are apt to antagonize and react against each other. It is the same as in the case of the motor nerves, which pass into sympathetic ganglia, a part of the motor energy is scattered off into out-of-the-way places and gradually reduced from work to mere heat. There must not be too many bearings of a question come up for discussion, if a prompt decision is required. The character of the Duke of Halifax, as given by Macauley, was one of indecision, because of the very versatility and wit of the man, that compelled him to see so many bearings of his subject, each of which was forever answering, rebutting and neutralizing the others.

The history of Winnifred, Countess of Nithsdale, whose husband took part in the Scotch rebellion of 1745, and was condemned to death for it, shows not only the decision and preserverance of her own character, but that she understood that the elements upon which a purpose must be formed, in order to be persistent, must not be opposed by others of a distracting nature. She determined upon a plan for her husband's rescue, by disguising him as a woman, in which it was necessary to have the co-operation of two other women. These she surprised into her service after all the other arrangements had been made, and pressed the execution of the plot before they had time to realize the risk they were incurring. They started for the prison in a coach, and she says, "When we were in the coach I never ceased talking that they might have no leisure to reflect. Their surprise and astonishment when I first opened my design to them had made them consent, without ever thinking of the consequences." The plot was cleverly managed by this ingenious woman, and was entirely successful.

A persistent purpose involves no principles not concerned in the formation of will. It is, in fact, the continuous re-formation of a will by the concurrence of all the stimuli involved at any time and every time. And the purpose is persistent only in the event that the stimuli are persistent. For example, A, who is in the clothing business in Minneapolis, hears that B, in Chicago, has a job lot to be sold at a bargain.

He resolves to go to Chicago, to-morrow, to see, and if they suit, to buy them. When the time comes to go a member of his family has become dangerously sick and he is afraid to leave, and so postpones going till next day. The motive to go is still the same, but is modified as to the time. This may happen the second, third and fourth day, the purpose to go remaining persistent because the stimuli which first formed it remain continuously the same. But on the fourth day, A learns that B, tired of waiting for him, has closed out the goods to another man. One of the chief factors that helped to form the purpose being now withdrawn, the purpose itself summarily terminates. Dr. Adam Clark spent twenty-five years in writing his commentaries on the Bible, and fifteen more in printing and publishing them; a rare instance of a persistent purpose. The motives which originally formed the purpose remained the same for a time after the work began, so that if counter motives had postponed it for some years, still it might have been commenced. But after its commencement the conditions which entered into the construction of the motives began to change. The doctor gradually discovered the task to be a much more difficult one than he had anticipated, and his own equipment and resources to be less adequate than he had *imagined.* On the other hand, while the stimulus of supposed *duty* and approval of *conscience*, mixed with the *expectation* of the approval of his friends and society remained the same impulse to the continued prosecution of the work; the real ability to do the work increased by the *habit* of working, and the amount still to be done constantly decreased. So that the balance of motives continued to be, on the whole, constantly formed in favor of the prosecution of the work until it was finally completed. After its completion he speaks of it as "a labor which, were it yet to commence, with the knowledge I now have of its difficulty, and my, in many respects, *inadequate means*, millions even of the gold of Ophir, and all the honors that could come from man, could not induce me to undertake. Now that it is finished, I regret not the labor; I have had the testimony of many learned, pious and judicious friends relative to the execution and usefulness of the work, &c."[1] In this case, and obviously it is the same in most cases, the motives were derived, in part, from stimuli which were only partial and incomplete transcripts of objective realities. A partial truth is, in reality, an untruth. The brain seldom has a complete impression from every part of any object in the environment, and of necessity, motives and wills are based upon incomplete and therefore only partially true data.

The force of the will is not the same in all directions in the case of any individual. An object, or class of objects, for the accomplishment of which one man will put forth his most intense exertion, will com-

[1] Clark's commentaries at the end of Malachi.

mand but a small share of the energies of another man. Of course no new principle is involved in this. Those impulses which are single and unopposed, form the strongest wills, other things being equal. Again, those impulses which result from the harmonizing of the greatest number of cerebral organs by any given stimulation, will develop the strongest wills, other things equal. Those impulses which originate in the effort to prevent a threatened rupture of such relationships as have been most habitual to our lives and to those of our ancestors, develop the most energetic wills, other things being equal.

It is the hereditary and acquired habit of caring for and protecting the young, that has established so close a relationship between the female mammal and her offspring. The resistance of the rupture of such relationships is often characterized by the greatest energy and vigor displayed by females of weak and vacillating will in other matters. So, oftentimes, in the preservation of his life, the veriest coward may become a hero, and surprise himself by the force of his action. That such wills are often formed upon very sudden impulse, in an almost automatic and instinctive manner, is nothing against the general view of the character and origin of the will here presented, but confirmatory of it.

The notion of free will is strongest in those who are vigorous, strong and healthy. The organization is such as to call for activity. It is, in fact, in a state of mobilization. It runs easily in response to the forces appropriate to move it. The mental part, inspired by the physical, presents desires and feelings to correspond with it. The individual feels like doing the things which there is energy for doing, from which we may infer the energy inspires the feeling. Each individual is inspired to the particular form of activity for which his bodily structure is appropriate. On the other hand, when his powers fail, which means when the machine decays and is difficult to be run, the buoyancy of feeling decays with it. He no longer feels himself master. His idea of freedom is not so vivid. He wants to rest, and be at peace. He more readily submits to the guidance of others. Death does not excite such a feeling of abhorrence as formerly; often it is longed for and welcomed.

It was pointed out in chapter 68 that our sense of responsibility for an action is, at bottom, a feeling of pain arising from the anticipation of painful sensations liable to follow the action.

If a man must act according to motives which assail him from without, the consciousness of the influence of these motives, and of the obligation or necessity he is under of yielding to them, constitute whatever sense of responsibility he has in connection with his action. No sense of responsibility attaches (at the time) to the acts of a man when drunk or in a condition of somnambulism, or delirium or insanity, or in

any condition in which the general run of motives do not arouse sensation in him, and so are inoperative in his case. We hold men morally responsible to the extent we perceive them to be under the restraint of cerebral motives.

Infants, idiots, the insane, the drunk, the untaught, &c., we perceive are incompetent to be controlled by the motives which govern those of mature and clear intellect, and so we say they are not responsible to those motives, and in governing those classes we endeavor to supply motives which will restrain them. If they have intellect enough to be instructed, we admonish them and let them go. If not, we punish them and let them go. If the memory of these things is enough to keep them straight, we say they are able to restrain themselves, and that they are responsible to these motives of memory, or they are morally responsible. If such motives do not control them, we lock them up; they are not morally responsible, that is, no motives can be erected in their brain which are sufficient to control them, so we control them by physical force and make them responsible to that alone. Under all circumstances they are bound. The free alone, if there were any such, could be accounted to be irresponsible. No conditioned being can be free; there can be, therefore, no irresponsibility in nature. The *feeling* of responsibility which is possessed by man and all the other animals which have a cerebrum and a memory, is proof that they are not free. It is singular that the sense of responsibility which we feel, should have been taken by anybody as a proof of our freedom. The sense of responsibility is a sense of obligation to do something or to leave something undone. It is an emotional sense and connects itself with various memory organs which express intimate relations of outward things to ourselves. It is a sense which results from a perception of the way in which certain external conditions will affect us with reference to our comfort or discomfort, pleasure or pain, happiness or unhappiness. It is the sensation of a state or condition of the brain which follows such perception, and precedes the will, the condition, and of course the sensation, of it disappearing when a will is formed as a sequel to it. In other words, this condition of the brain occurs in the great majority of cases in which a motor will is formed and is then an element in its formation. The sensation of it is a sensation of a striking of the balance of motives and of the imminent presence among them of motives of personal liability and penalty.

The sense of responsibility is closely allied to the sense of duty, which was mentioned in chapter 68 ; undoubtedly the sense of duty could have arisen, in the first place, only in connection with a sense of penalty or loss for neglected duty. But the practice and sentiment of duty might, after much repetition, become a matter of habit and finally a matter of instinct, and its originating cause be lost sight of. Thus, watch dogs,

hunting dogs and shepherd dogs fall into their hereditary duties with a sense of responsibility, no doubt, but of a different sort from that which inspired their ancestors while they were acquiring their habit. Then, their motives were to please their masters and escape the corporal punishment they found to follow failure in their tasks. Now, their organs having become differentiated to the automatic performance of these operations, the sense of responsibility no longer depends upon the recollection of corporal pain, but it is the uneasiness which results from the presence of an appropriate stimulus for driving such organs, felt during the time the organs are restrained or prevented by any other motive from acting in response to the stimulation. That is, the dog no longer realizes a responsibility to his master and his whip but to his own conscience. As with dogs so with men. The requirements of social intercourse and mutual help and restraint, have produced in us organs whose functions are to impel us to perform the duties exacted by these requirements. When from any cause these functions are balked, the resulting inharmony is productive of the uneasy sense of violated conscience; of duty neglected or put aside. The habits of these organs, then, supersede and stand to us instead of the direct impact of external stimuli, and we are said to act from moral motives instead of physical motives.

Our feeling of responsibility, therefore, is a sensation of being bound, instead of a sensation of freedom. We are constantly driven by impulses of greater or less force, which are usually the resultants of conflicting motives, and which are therefore decisive by so small a majority that we are apt to think that we had equal motive to do something else. A man will say, "Why, I could have done that other thing just as well as not, if I had thought of it," or "I could have done so and so if I had wanted to, but I did not want to." He did not want to because, although a small motive would have changed his will, the motive at the moment was not present, although it might have been among the inactive memories of his cerebral organs. The knowledge that the elements of causes, which are already in the cortical organs, would, if they had been in action, have altered the result, leads to the erroneous feeling, in such cases, that the causes of the will, or at least of the action, are dominated by self.

It is not reflected that these organs of the internal senses are only the lurking places of the external forces, which are introduced from without, in the first place, and placed there half in ambuscade. They look so naturalized there, we are apt to forget their foreign origin. It is only as long as we are conscious of other motives still in abeyance, which have had no influence upon our action, but which would have had if they had not been dormant, that this subjective feeling of freedom endures. We feel, in such case, as if the will was contingent, and might

have been different. But after all motives from external and internal senses have had their influence in forming the will, we are then conscious it could not be different; our sense of freedom vanishes, and we feel ourselves in the grasp of an iron necessity that we cannot escape or will to escape, because all the motives are concentrated in the formation of that very iron necessity, the final purpose, and no antagonizing will is possible. Luther said, "Here I stand, I *cannot* do otherwise." He knew he *could* not because he felt there were no unconsidered motives in the background that could disturb the will already formed. And so we all feel in the presence of a purpose which we know to be final. We *cannot* do otherwise.

It is often said that we have no right to hold others responsible for their acts or to punish them for wrong doing unless they are free. But if we give this a little attention, it will be seen that we hold men responsible, not in proportion to the degree in which we suppose them to be free, but in proportion to the value of the motives to which they are exposed and by which they are actuated according to our estimate of that value as a *binding* force. Thus, if an insane man commits a theft, we say he is not responsible, and we excuse him, because we recognize that the ordinary motives which compel men to be honest are absent and do not dominate his life. So far as these motives go, he is free. He steals then because he is at liberty to do so, and though we do not blame him, nevertheless we proceed to stop him by curtailing that liberty; and if we cannot furnish moral restraint which will make him *feel* that he is not at liberty to steal, we place him in confinement where he will *see* that he is not. When a sane man steals, it is evident that he, too, has too much freedom from the compulsion of moral motives, and we put him in confinement, but for a purpose somewhat different. Imprisonment in the case of the insane man is only for physical restraint, and will last indefinitely as long as the man is insane. In the case of the sane thief, it is for such specified term, as in the opinion of the law or the honorable court, will be required to erect moral restraints in the man's brain. If the man behaves himself after this, we say he has come under the influence of moral motives. And we thus define moral motives to be the restraints imposed against the performance of certain acts by the memory of unpleasant results associated with them. In thus supplying artificial stimuli to form the will, we are imitating nature and giving an object lesson like those learned by our ancestors before the advent of moral instincts. Our punishments are founded upon the fact that all restraints are painful, and they are designed to afford to the culprit a memory of pain greater than the pain of the restraint of the crimal acts. But we often learn to do the correct thing empirically without being able to give logical or scientific reasons for it. Men have been punished, and prop-

erly punished, when the reason assigned for it, very improperly, was that they were to *blame*; by which charge the idea is rather vaguely conveyed that the criminal act was performed without motive. It used to be said that criminal acts were done at the instigation of the devil. Sometimes it is said they are done from motives, but they are wrong motives; and the criminal has been thought worthy of blame for the motives by which he was actuated. *Blame* is the expression of an uneasy and inharmonious state of cerebral action produced in ourselves by the acts of another (or the acts of other organs in ourselves). If a person is blameworthy for the motives which actuate him, then the person entertaining the feeling which blames may be called to answer why he has such feeling; and he often is, because it frequently happens that what one persons blames, another commends. The person who blames, justifies himself by the plea that he was compelled to by the motives, and so also may the culprit justify himself. We cannot then logically blame a man for the motives which operate him, nor yet for the state of feeling which his action produces in us. But properly analyzed, this latter is what we do, since our feelings, and not his motions, are the direct antecedent cause of the expression of blame. But since our feelings are the resultant sensations produced by the other man's action upon our own organs of internal sensation, these organs of ours share the responsibility for our state of feeling, and may therefore be as much to "blame" as the motives of the other man.

On the whole, it is obvious that we cannot help the feelings prompted in us by the acts of another, and that no more could he, ***under the circumstances***, help the feelings prompted in him which led to the actions which disturbed us. The actions on both sides are necessary, and could not, under the circumstances, have happened otherwise. But the action of the criminal in provoking the resentment, blame and retaliation of society, tends to put a check upon itself, because the resentment and retaliation of society bring pain to the criminal, the experience and memory of which become motives in future for restraining the commission of crime. A perception of this fact by society, causes the expression of resentment and measures of retaliation to be reduced to certainty and definiteness; and so the foundation of the criminal code is laid. And so the effect is to supply the criminally inclined with motives to restrain his criminal actions. It is evident that this procedure would be absurd if men's wills were not subject to the control of motives. Whatever theory of freedom we may think we entertain, we know as a practical fact, that all men are in bondage to motives of one sort or another. and a large part of our intercourse with others is for the purpose of binding them in some particular for our benefit. It is sometimes said a man is free to choose. This is not quite true. He is free to *take* the

thing he chooses, but his choice is decided by the motives, and could not be otherwise. Nor is it quite true that he is *free* to take the thing he chooses; he is *bound* to take it. He cannot do otherwise than take it, any more than his hand can refuse to obey his will. Nor can he possibly take a thing till he does choose to. He is the slave of the choice born of motives supplied originally by the environment. As said above, we practice on this fact however we may theorize. The social organization has thrown around the individual every bond of control which our present civilization has been able to invent, with a view to compel conformity to the social interests. The legislature, the school, the church, the press, the courts, are so many agencies for the purpose of creating the motives by which we prefer to see our neighbors governed. They certainly would not exist if men were free from the influence of motives. We know that men will succumb to the most powerful motives, and there is therefore a sharp competition between them, and the fittest motives remain the effectual masters of our lives.

Our feeling of responsibility, then, is a feeling that we are under obligation or compulsion to do certain things, and is accompanied by a sub-sense of impending penalty, and a more or less vague and "fearful looking for of judgment" if we fail. It is the very reverse of a sense of freedom. In short, we are in the same condition as a steam engine. When steam is admitted to the cylinder it is free to go, but by no means free not to go. If it is free to go it is also *bound* to go. We generally excuse a man for doing that which he is conscientious in doing. Why? Because somehow we feel he is under a compulsion, and could not do otherwise. We therefore recognize that in obeying his conscience he is not free.

CHAPTER LXXI.

THE EMOTIONS.

The distinction made between voluntary and emotional activities has its chief use in rendering a large subject more manageable in our treatment of it. But the distinction does not exist in nature. The cortex of the brain is full of the organs of the memories relating to all of our experiences and observations. Most of these connect themselves with our personality in a pleasurable or painful manner, but some are nearly indifferent, and give neither pleasure nor pain. These last seldom become the bases of any of our actions, although they may intervene as modifiers, as to time, place, mode, etc. The former ones are our emotional organs and form the basis of the most if not all of our actions. Of course our personality is involved vastly more in some of

these memories than in others; and in this respect the organs range all the way from comparative indifference, to a condition in which the memory is a register of personal incidents, or relationships, of such a violently inharmonious and unhappy nature, that their recollection produces extreme nervous agitation and painful excitement. Between these two extremes there are the organs whose recollections furnish the the stimulations for the great majority of our actions. These recollections are for the most part satisfactory and pleasurable in various degrees, and the stimulations arising from them keep in operation the ordinary activities of life. Any of the organs, even those ordinarily giving pleasurable recollections, may be stimulated to a painful degree by sudden and violent agitations. We sometimes hear of a person being killed by a sudden joy; as when a mother, plunged into the deepest grief by the supposed violent death of a son, is suddenly allowed to see him alive and well. We may suppose that the incoming stimulus, which in its relations to many of the organs would be harmonious and productive of joy, is in relation to the one registering the unhappy memory radically and violently antagonistical, and therefore tends to its rupture and disintegration. This, if done slowly, would do no harm, and would give rise to pleasurable sensations, but performed with a violent suddenness it causes a lesion of cerebral or nervous tissue or of blood vessels, or shocks the heart by an excessive and fatal nervous stimulation. The converse is also true, in which the already differentiated organ of pleasurable memories is suddenly antagonized by an incoming stimulus of a diametrically opposite sort. Antagonistical organs of the most radical sort, may be and often are, introduced by a gradual process in which a later so far subverts a former, that its reactions no longer produce a vivid sensation But when such antagonisms are too sudden and violent, mischief is apt to result.

Almost every person has one or more organs of grievous memory which time and diversion of attention may soften and obscure, but which cannot be entirely obliterated or buried. Whenever a new sensory stimulation is of a nature to connect itself with one of these, it fastens attention upon it and revives the painful memory. There are some people whose lives have been so full of bitter griefs, disappointments and reverses, that they are liable to be unpleasantly reminded and depressed by a great many sorts of stimulations, often even those which usually give joy and satisfaction to people in good health. These organs of painful memories may become so abnormally erethised and excited that their influence upon the life and cerebral actions are morbidly excessive and dominating, and the subject of them becomes emotionally unsound. Those pursuits called purely intellectual, are always connected with our personality by sensations of satisfaction.

and often of the most exquisite pleasure. They could never become pursuits if it were not so. The organs involved with these, like others, are liable to excessive development and morbid stimulation, and the subject becomes a hobbyist, a crank, or a lunatic.

From the forgoing it is obvious that, as remarked at the beginning, there is no natural separation of the emotional from the intellectual, either in organs or their active expressions. Every organ in the cerebrum possessed of a memory is an intellectual organ. It is likewise emotional in the degree in which its recollection is also sensation. The sensation is pleasurable or painful in the ratio of the harmony, or inharmony, with which the action is connected, with so much of our personality as may have been already developed. Therefore, no matter in how deliberate and well considered a manner a determination or will is arrived at, sensations, that is, emotions, have constituted its motives. If an act be performed under the excitement of a powerful and sudden sensory stimulation which proceeds to rapid execution, but little time is left for the interference of many of those organs in the cerebrum whose constitution would ordinarily cause them to participate in the action. We often speak of such an action as involuntary. But the simple fact of its being done rapidly does not make it so. It may not be well considered, and be different from what it would have been if it had been well considered and modified by all the related organs; but hardly any voluntary action is the result of a will formed under the influence of all the possibly related ideas in the cerebrum. Generally but a few and often only one idea is the motive of a will. The will is formed by whatever stimuli happen to be present and active, and those potential ones which remain dormant in the background, of which there is in every case a large number, though not the same in any two cases, have nothing to do with it. When one motive is dominant, one motive is sufficient to form a will, and that it may be overwhelmingly so, does not make the will formed any less a will. Whatever is prompted by grief, hatred, malice anger, revenge, fear, hope, caution, benevolence, malevolence, patriotism, humor, defense, indignation, love, policy, is voluntary. Whether the will be formed suddenly or deliberately by one or more of these motives, it is still a will, and the stimulation arising from its formation takes the same track down the efferent nerves from the cerebrum. Probably the reason why it has ever seemed proper to make the distinction of voluntary and involuntary between acts prompted by deliberate emotional stimuli and the same stimuli when sudden, has arisen from the collision of the notion of free agency as thought to be illustrated in the former, and the fact of necessity as plainly shown in the latter. When it is understood that the so-called voluntary acts are just as necessary as the others, this distinction will disappear.

There are, indeed, muscular movements resulting from cerebral actions which at first appear to justify the title of involuntary, in the ordinary meaning of the term. Thus the squirming and laughing which result from tickling, may be simply the reflex action of the lower centers—medulla, spinal cord, &c.; but if they result from merely pointing the finger and raising the *suggestion* of tickling, they are caused by reaction from cerebral memory organs. Nevertheless, on reflection, we shall see that such actions have no right to a classification independent from other cerebral actions. There is no dividing line and no place for one. There may be great differences in the facility with which certain muscles respond when stimulations overflow from certain cerebral organs or combinations of organs.

There are, in fact, certain definite relations in some cases between a certain muscle and a particular brain organ, so that it is an established habit, that when the latter is stimulated, the stimulus passes on to the former. In other cases, and generally in complicated and occasional cases, the action is contingent and antecedently problematical, but it is still worked out by the cerebral currents upon the lines of least resistance, just as the more simple and definite cases are, and is just as mechanical as they. In all cases, whether it arouses a sensation of itself or not, there must be the chain of nervous movements, long or short, extending from the memory organ or organs, to the muscle, and it must contain the link or links which, when we are conscious of them, we call the will.

As observed in chapter 60, there is a class of actions which are coordinated in the medulla oblongata, and executed in the various muscles, especially those of the face, throat, &c., which are called *expressions*. The surplus stimulation accumulating in the medulla, overflows to these muscles, and would alone give them certain sorts of tensions and contractions which would constitute the expression of *medullary states* or conditions. I suppose the face of a complete idiot reflects the expression which stimulations from the medulla oblongata alone would give. But this expression is interfered with by stimulations from the cerebrum. The cerebrum, like the medulla, accumulates a surplus of nervous energy, which likewise flows off and adds its influence to that of the medulla, and modifies the expression of the face, &c., given by it. It is easy to distinguish the expression of the lower centers from that of the upper. We speak of an idiotic expression and an intelligent expression. But there are all degrees of intelligent expression, as there are all degrees of cerebral development and excitement. We can perceive the change in the expression of an infant as it begins to accumulate ideas. The stimulation which finds its outlet in muscular expression, comes from the same sources (the cerebral organs) which, when

the excitement is stronger, furnish the purposive actions. When the cerebral activity is at its lowest, the sensations are of the most subdued kind, and we may be said to be in a sub-conscious condition. The tensions and the currents are of the weakest kind; yet the fact that there is any muscular expression at all, is proof of their presence, and consequently of the presence of those activities which constitute the revival (in a very weak way) of the memories of the organs. In other words, the state of consciousness which produces expression, is a state in which there is gentle and general stimulation of the majority, or of a large number of memory organs, and an overflow from them to the muscles. This stimulation arises from the mere presence and pulsation of the blood in the brain, and, as observed elsewhere, starts up as soon as the circulation increases upon our waking in the morning, and continues while we are awake. It does not entirely cease while we sleep, but is greatly reduced. In this state of general consciousness, the subdued excitement may be spread more or less evenly amongst the organs, and no memory made more prominent than the rest. But this state of equilibrium is disturbed the instant a new sensory stimulation is received from the environment. New tensions and currents are formed, and centers of attention are established. The sensations of these new activities are of proportional intensity; and the overflow currents which may pass out to the muscles, throw them into contractions and tensions, which constitute new modes of expression, and are, in fact, the true expressions of the state of the organs at the moment. We generally speak of the former ordinary expressions as involuntary, and the latter conditional ones as voluntary. But it is obvious that they both belong to the same class, and are operated in the same mechanical way.

The average state of the organs of the cerebrum impresses itself upon many of our muscles constantly, in giving them a subdued and moderate tension, or more or less fixed position, which remains much the same during life, except that it is subject to a slow modification corresponding with the modification which takes place in the cerebral organs themselves. This expression, as observed above, is especially marked in the muscles of the face, although it is stamped upon the general muscles of the body, giving peculiarities of attitude, posture and gesture. As just observed it undergoes a gradual development or change during life, as the cerebral organs change. If physiognomy were an exact science it would be possible, by comparing a fac simile of the expression of a man at twenty with another of the same man at forty, to tell what his habits of life and thought had been during the interval. It is easy for any ordinary observer to distinguish the difference of expression between one who has cultivated his brain and another whose occupation has been chiefly muscular, or between an abstemious

person and one of good stomach, or between a person subject to griefs and disappointments and one with whom life has been agreeable. We constantly judge the general character by the expression and speech of a man as gloomy or surly, or kind or light-hearted, or simple or cunning, or bold or cowardly, brutal or benevolent, sour tempered or sweet, busy or at leisure, in prosperity or adversity, intelligent or stupid, humble or arrogant. Besides the more or less constant and steady expression which the ordinary tension of the muscles gives, every stimulation of the cerebral centers which control these muscles causes a disturbance of the tension, and consequently of the expression, so that we can often get an idea of the sort of organs under stimulation for the time being, by the change in the expression. Thus we judge whether a person is angry or pleased, or bored or grieved, or anxious or careless, impatient or satisfied. We form our judgments not alone from the expression of the facial muscles but from that of the muscles of the limbs which give attitude to the body and character to the movements. If a man is humble or arrogant, positive or negative, mild or fierce, he shows it in his carriage and posture; and the usual and natural posture is liable to exaggerations or modifications when the organs are stimulated. When a man is provoked to resentment, his rigid and indignant attitude, his flashing eyes and scowling face, plainly indicate the fact. We know very well what sort of difference in cerebral action is indicated between the dog who makes himself as small as possible and retreats with his tail between his legs, and the one that stands rigid, shows his teeth, and raises the hair on his back. The attitude of indignation is caused by a state of certain cerebral organs and, as we say, is their expression. If the excited state of the organs becomes more intense, the result will probably be angry words, "I have a great mind to knock you down," and these are the natural expressions of that state. If the excitement increases, the result may be blows, and there is no reason why these are not the natural expressions of *that* state of excitement. A blow is an act of the will, and it is in this case produced by an excess of the same sort of stimulation which in less intense degrees produces the words, postures, and expressions we term emotional. Thus emotion and will belong to the same catenation, and are not to be reckoned as antagonistical principles, but as antecedent and consequent. The emotion then is to be regarded as a will former, and the stronger the emotion, the more vehement the will. I have seen a story of a timid little boy who was obliged to go to bed in a dark room. He found by experience that he could frighten himself across the forbidding tract which lay between the door and his bed, by the cry of, rats! under the stimulation of which, he was accustomed to make the rush. Soldiers in battle likewise fortify their determination by emotional stimulation, in the shape of battle cries, huzzahs, martial music, etc.

Those forms of the expressions of the habitual feelings or emotions which are usual and automatic, have become so through long habit of the present generation, and of our ancestors; the effects of the habits of our ancestors being transmitted to us in the shape of predispositions to fall into the same habits. Thus, a feeling of obsequiousness, acting as a stimulus, produces a tension on certain muscles of the face, eyes, body, neck and limbs, producing that attitude and expression which we speak of as humble and deferential. This attitude is assumed sub-consciously as the automatic reaction of the brain we inherited from our ancestors. This structure, modified by the use made of it in us, will be handed down to our posterity as one of the bases of *their* instinctive habits, and so on. The stimuli which are reflected from the various centers of emotion when powerful may produce consciousness, and they may be counteracted and neutralized by stimuli from other centers of ideation, or they may burst forth in an uncontrollable manner in the movement of limbs, or in tears, sobs, moans, outcries, laughter, &c. These movements are to be regarded as the mechanical equivalents of the tensions of the emotional stimuli, of which they are the usual and therefore "natural" expressions. But the tension of these stimuli may be worked off by other mechanical movements. A half-idiotic youth in the lunatic asylum at Boston, was subject to violent paroxysms of anger. It was suggested to put him at some fatiguing work, with a view of moderating his passionate demonstrations. He was, willingly enough on his part, set to sawing wood for two or three hours every day except Sunday. The effect was that he was tame enough every day he worked, his outrageous conduct breaking out only on Sunday. When the task was afterward appointed for that day too, there was no longer any trouble with him. (Dr. Howe.) Anger which usually manifests itself by an explosion of oaths or personal abuse, violent gesticulations, flashing of the eyes, tears, hysterical laughter, &c., may also, as in the above case, find vent in sawing wood. Any other vigorous exercise would answer, as rapid walking, &c. Some persons will slam a door, stamp the foot, kick the dog, &c., the principle being the diversion of attention and blood from the excited organ.

The restraint of the physical expressions of the emotions, by maintaining the violent excessive and prolonged erethism of the brain cells involved, is productive of pain or uneasiness and an apparent effort on the part of the stimulus to find vent. It is well known that pent up grief may disastrously affect the whole nervous system, and through it, the general vitality. Not a few instances of death from grief are on record. But where the demonstrations of grief are violent, it is usually short lived, however real it may be. Diversion is the best remedy for painful tensions of the emotional organs. Because, first, the excitement

of other centers by external stimuli divert to them the blood supply, and second, by furnishing other outlets for the internal stimuli than those of the emotions, the excitement of those centers is reduced. One great emotion will neutralize a smaller one. Enemies become friends when both are threatened by a common peril. Wild beasts cease to fear men when confronted by some terrible natural calamity.

Starvation is a mortal enemy of emotions. Deprived of proper physical nourishment from the blood, all the brain centers rapidly lose their force and activity. The sensations expressed by pity, love, hate, anger, revenge, and all the rest, disappear in the presence of hunger, and nothing so quickly subdues a ravenous beast.

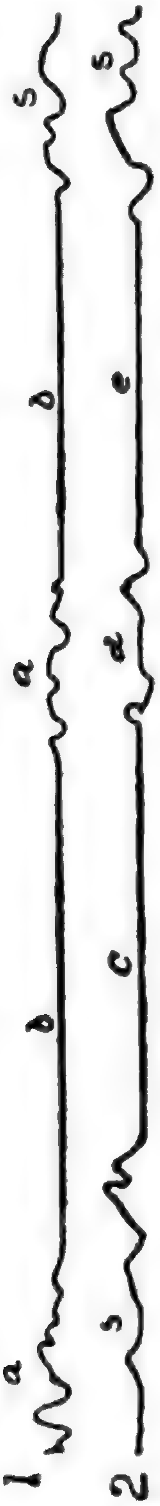

Fig. 378.

Fig. 378.—Diagrams showing interruptions by sensory stimuli of automatic movements of infants.

a, a, s, d.—Periods in which the automatic movements were performed.
b, b.—Periods of musical sound during which attention was diverted to the sound and the movements stopped.
c, e.—Periods in which light was exhibited.
d.—Light withdrawn.

In experimenting with infants, it has been observed that their automatic or spontaneous movements have been arrested by a stimulation of sight or sound and temporarily suspended. The diagram, from Warner, shows this experiment graphically. Several authors call this action of the sound or light "inhibitory." During the continuance of the stimulation by the light or sound, the *attention* of the child was fixed, that is, the circulation of the blood and the accumulated nervous energy which before went to the muscles, was now directed by the stimulus to the brain and went to the differentiation of brain tissues. Such inhibition is not a negative process, but simply divertive and directive, and the term is not a good one for the case. If the cerebral hemispheres be taken out of a live frog, leaving the optic thalami, optic lobes, medulla oblongata and spinal cord uninjured, reflex action can be got by irritating a limb, say a toe, by dipping it into very dilute sulphuric acid. After a moment, the length of which must be noted, the limb will be withdrawn. If the experiment be tried of putting the toe in the acid, and at the same time stimulating the optic thalami, or optic lobes, by touching with a crystal of rock salt, it will be found that the reflex withdrawal of the toe will require a much greater length of time. This, too, is inaptly explained as resulting from the "inhibitory" action of the optic thalami, or optic lobes. The fact is, I take it, that when these lobes are irritated a part of the energ

and blood supply are diverted to them, and so much less energy is left to operate the toe. This is the same in principle and operation as the interfering effect of the will, or of an emotion upon another emotion, or upon a reflex or instinctive action. If a lady feels herself about to blush she cannot stop it by simply wishing to; that would only aggravate the expression by directing more attention to it. But if her thoughts could be diverted from herself to some external object, a new center of attention would be established in the brain, and a new direction given to the blood supply, and the blush relieved.

Some of the movements which follow from excessive emotions, are those which tend to ward off, or counteract the cause which produces the uneasy state, and we fall into them as a result of habit, very often, when they do not help us directly, except in the way mentioned above, of diverting the energy and reducing the intensity of the uneasy state. In such cases the action has, through the habit of the organs, become automatic, so that the excitement glides into a frictionless channel, which, at some time in the remote past, might have been traversed only by a purposive movement. But a large number of emotional actions are not purposive, and never were. The facial expressions of children under pain or pleasure, must be regarded as the effects of the overflow of stimulations into channels of least resistance, indeed, but their grimaces and contortions could never have been purposive. At the same time, however, it is easy to see how they might have been of service in calling attention to their wants, and so, by selection, have become fixed and constant. The effects of the emotions on the different secretions, of course, were never purposive, and most of them are not under any sort of voluntary control. The change in the color of the hair is one remarkable example. There are many cases in which, under the influence of terror, it has changed from black to white in one night, and one case is recorded in which the hair of a criminal in India, brought out for execution, changed color so rapidly it could be perceived by the eye. Some effects on the secretion of the milk glands have been mentioned in a former chapter. This secretion is very susceptible to disturbances of several of the emotions, and so are those of the liver, the kidneys, the salivary glands, the tear glands, the stomach and intestines. The heart and some of the blood vessels, too, are strongly affected by appropriate emotions.

It is reported that the facial nerve may become so paralyzed as to destroy the expression, the tension of the muscles becoming, in part, relaxed, and the mouth drawn to one side. The ordinary automatic movements of expression, and involuntary winking, do not take place. Yet, there may be still voluntary power to contract the muscles of the face, and to wink the eyelids. This would happen if the motor fibres leading from the medulla oblongata to the face were to become paralyzed,

while those from the cerebrum to the face remained functional. The portion of the expression depending on the medulla, would be abolished.

As before observed, we are born with our muscles each connected primarily with a certain tract of brain. Indirectly, each muscle is connected with every tract, since every tract is connected with every other. The number of motives by which a will is formed to move any limb, is practically infinite. The same movement of a leg follows any one of a thousand purposes. Likewise the overflow of many different sorts of emotion affects the same muscle and produces the same motor effects. Tears for example, are produced by emotions of very different, and even contrary, natures. Tears are shed from feelings of physical pain, from grief, disappointment, rage, vexation, joy, laughter, sympathy, and also when there is no emotion; from a dazzling light, exposure of the face to a chilly wind, coughing, vomiting, yawning, severe irritation of the eyes by foreign substances, irritation of the nostrils and of the fauces, inflammations, &c. If we consider in how many ways, and in how many parts of the body, we can suffer physical pain, from what numerous causes we can suffer grief, rage or disappointment, and from what numerous circumstances we can experience excessive joy or sympathy, and by how great a number of circumstances we can be excited to laughter, &c., we shall see that the single emotional causes competent to produce tears, are well-nigh innumerable. Add to these the mechanical causes which act upon the same nerves through reflex action, as mentioned above, and the list is greatly increased. The excessive stimulation of a vast number of cerebral parts is propagated to the tear glands and to the orbicularis, and a few other muscles about the face and eyes, whose compression tends to the secretion and emission of tears. (See fig. 66.) The same muscles are all subject to voluntary contraction. A good actor will, by purposive contractions of the facial muscles, produce very deceptive imitations of the ordinary emotional expressions, even to the production of tears. The same sort of observations apply equally to many other attitudes and demonstrations of emotion. They may become attitudes and demonstrations of intellectual states, and consequently purposive. But the two run into one another in such a complicated manner that they cannot be separated into different categories, either in respect to their necessary origin in environal causes or in their termination in muscular contraction. In short, there is no radical structural difference in the manner in which the brain is worked by different stimuli, nor in the outcome of that work as exhibited in muscle contraction and expression. We are justified in characterizing the last step in the cerebral action preceding muscle contraction, by the same term for all the stimuli. If we say purposive will, we may

also say emotional will, since emotions lie behind all purposes. But all such distinctions can be made only for the sake of convenience of discussion.

It would be curious, if it were possible, to trace the origin of the different emotional expressions which have descended to us as matters of involuntary habit. We have seen all along how the different parts of our bodies have been molded and shaped by the actions which the external stimuli have put upon them through the ages. A great many of our present movements of expression seem to be quite useless and we do not readily see why such and such movements and gestures should follow such cerebral states. But in many cases it is possible to discover how these movements have once been useful, and having become habitual, have descended to us and remain as heirlooms of a more or less rudimentary character.

The corrugator muscles of the forehead (see fig. 66) by their contraction produce frowning. The contraction of these muscles occurs when the eyes are exposed to too much light, and when it is necessary to intently concentrate the vision upon something difficult to be seen, and the seeing of which makes it necessary to exclude light reflected from other objects beside the one looked at. In such cases the pyramidal and orbicular muscles are likewise often contracted, acting to the same end, and the action may be reflex or automatic, or consciously voluntary. But in all the cases the same physiological process of an increased determination of the blood to the muscles involved, takes place preceding and during their contraction. We have seen that this is the process which we call *attention* in voluntary actions, and since the same thing occurs with involuntary actions we have what may properly be termed *involuntary attention.* We find a good example of this involuntary attention in the case of blushing. It is likely that the contraction of these particular muscles, the corrugators, first became habitual through attention following visual stimuli, second, certain cerebral activities became associated with these visual stimulations, and nervous connections became established between the contracting muscles and cerebral tracts. Third, it would finally become possible for the muscles to be automatically contracted by the overflow stimulation from these connected cerebral tracts whenever the latter were excited, regardless of the source of the excitation. Thus we find that the frown caused by the contraction of the corrugators results from close attention and puzzled occupation of various sorts, physical or cerebral. To be puzzled includes a strong and earnest cerebral attention. And in some cases the overflow or excess of this, passes to the corrugators as the habitual and easiest route. We are seldom merely puzzled or baffled; there goes with this state, as a consequence of it, generally, a

feeling of vexation, chagrin, disappointment, anger, or rage, so that we say of a person, that he frowns with vexation, with anger, etc. This explanation, then, involves the idea that a habit of organic action, differentiated by one sort of stimulation, may be kept up and continued by another stimulus, if not too unlike the first; as a dog thrown in the water will swim by nearly the some movements he makes in walking. Frowning is not the only expression of anger, rage, and other emotions of the sort; but various sorts of muscular actions, including those concerned in the voice, follow these states. An infant displeased or in pain, will yell at the top of its voice and work all its limbs vigorously at the same time. The scream is preceded and accompanied by frowning, and also by the contraction of the orbicular and other muscles by which the eyes are compressed and the tears driven out. In adults too the expressions do not stop at frowning when the emotions are strong, but proceed to various kinds of muscular or vocal demonstrations, differing in different people.

If any part of the body be gently spanked by repeated blows of the open hand, there will be an increase in the warmth of the place; an increase of the flow of blood thither, and a reddening of the surface. These effects are of course more intense in those parts best supplied with blood-vessels. The same parts are also, as a rule, best supplied with nerves, and the effects of the blows in cerebral sensation are in like ratio to the effects on the skin. Our internal sense organs in the cerebrum are more intimately connected with these more sensitive parts of the skin than with those parts less freely supplied with blood-vessels and nerves. Or, in other words, our internal sense organs are intimate with the different parts of the skin in the same proportion in which the environment is intimate with them. The same principle applies to the relationship between the internal sense organs and the different muscles; they have influence and control over muscle contraction, whether it be automatic or purposive, in proportion as these muscles are stimulated to move the parts they are connected with, by either threatening or inviting conditions of the environment. Thus, the muscles of the eyelid are extremely active in avoiding threatened danger, while those of the ear are seldom or never, moved. The environment furnishes no motive for their action, consequently they are ignored by the internal senses.

The face is a part of the body necessarily much put forward and exposed to the impact of the influences in the environment. It is, more than other parts, exposed to the action of wind, sun and storm; in it are situated the organs of sight, smell and taste, together with the vocal organs, and all associated with a large number of muscles and nerves necessary for their protection and successful operation, and it is the part which represents the personality of the individual in his social relations,

and is presented to and addressed by others. Thus, receiving the greatest attention from the environment, it likewise receives the greatest attention from our internal senses, and the impact of the external stimulations of various kinds upon the face and its belongings, passing up the afferent nerves to the internal sense organs, provokes from them the return stimulation of attention, purposive or automatic, which sends the blood into the numerous capillaries of some part of the face or its muscles. The face having thus, first, for a long time been the outlet for overflow or return stimulations provoked by the action of environing stimuli upon itself, at last, through the facility thus attained, has become an outlet for the overflow of excitation from many organs of internal sensation, which receive their original stimulation from the senses of hearing or touch. In other words, through use or habit, the direction towards the face is one of the routes from the brain, of least resistance for the flow of superfluous excitation, so that the action which it sets up there indicates which cerebral organs are under excitement. Among the many indications impressed upon the face is the flushing or reddening which follows various kinds of cerebral emotion. The direct physiological antecedent of the reddening of the face, is the expansion of the arterial capillaries under nervous stimulation from the internal sense organs, by which the quantity of blood directly under the epidermis is increased, or it may be increased by the increase in the rapidity of the general circulation through muscular activity and increased waste of tissue, or from waste occasioned by disease. The reddening of the face, more than other parts of the body, from so many different causes, shows it to be, as stated above, a ready waste-gate of excitation.

The faces of monkeys redden from passion, showing that the differentiation of the face, as an index of cerebral states, began before our race. In man the face is reddened by the erection of organs, which produce rage, fury, anger, puzzled vexation, injured pride, shame, modesty, mortification, self consciousness, disappointment, joy, hilarity, amusement, triumph, and many other forms of emotional demonstrations. But the principle is the same in all. The easy overflow of stimulation toward the face would not have become so much the rule had not the face have become so much a center of attention, first, by the environment, and second, by the organs of internal sensation. The different causes which produce the reddening of the face, are usually betrayed by accompanying circumstances. We can generally tell whether a person is red from fever or anger, mortification or shame, &c. The reddening from self-attention and shame is called blushing. As a rule, with civilized races, blushing is confined to the face, unless the emotion is strong, when it may overflow to the ears and neck, and sometimes even to the hands and wrists. "When the sympathetic nerve is divided on the side of the

head, the capillaries on this side are relaxed and become filled with blood, causing the skin to redden and to grow hot, and at the same time the temperature within the cranium on the same side rises. Inflammation of the membranes of the brain, leads to the engorgement of the face, ears and eyes with blood. The first stage of an epileptic fit appears to be the contraction of the vessels of the brain, and the first outward manifestation is an extreme pallor of countenance." (Darwin on Emotions.)

Darwin gives the case of a sick lady at an asylum, who, on being approached by Dr. Brown and his assistants, blushed deeply over her cheeks and temples. When the doctor uncovered her chest to examine her lungs, a brilliant blush extended over the upper part of it and a considerable distance downward between the breasts. This is a curious instance of a blush following a conscious attention in what is probably an unusual direction. People of Malacca, who go nearly naked, have been at times observed to blush, not only on the face, but the neck, breast and arms, and even as far down as the waist.

Everybody has experienced, or observed, ***horripilation***, or as it is more commonly called, ***goose-skin***. This is an elevation of the hairs, &c., on the surface of the body towards an erect position and their slight protrusion, giving the skin an appearance of being covered with pimples. It sometimes feels like a cold thrill passing over the skin. It occurs with a general chilliness preceding fever, and upon exposure of the body to a chilly air, and it may be provoked locally by tickling an adjoining part. It also occurs under the influence of certain emotions, as sudden terror or surprise by something horrible or startling.

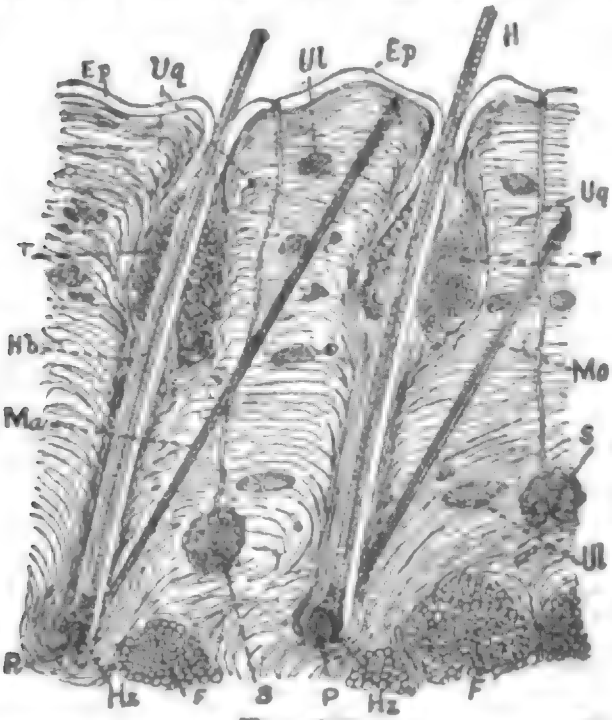

Fig. 379.

Fig. 379.—*Section through Human Scalp.*
Ep.—Epidermis.
Ul.—Transverse bands of the connective tissue.
Uq.—Longitudinal bands of same.
H.—Hair.
Hz.—Root of Hair.
P.—Papilla of Hair.
Hb.—Hair follicle.
Ma.—*Erector pili muscles*, their contraction pulls up the hair in horripilation.
T.—Sebaceous or oil glands.
S.—Sweat glands.
F.—Fat body

The hairs ordinarily stand in the skin in an oblique position. To the hair-sac at the bottom of each hair are attached minute fibres of unstriated muscle called *arrectores pili* (see fig. 379), which, when they contract, pull the root of the hair in such a way as to straighten it up. (See Job 4 : 15.) This action in man is entirely reflex and unpurposive, although when occasioned by emotion, the stimulation passes through the cerebral organs. This,

then, is another case of the overflow of stimulation of a certain class; that is, coming from organs having certain connections—to the periphery of the body, and there ending in mechanical demonstrations in the unpurposive contraction of these unstriated muscles. Horripilation is common to all the hairy mammals, to the birds, and to some reptiles. The erection of the hair along the back, especially over the shoulders, and in some cases over almost the whole body, and sometimes on the tail, has been observed in monkeys, baboons, chimpanzees, gorillas, the hyena, cat, dog, lion, bat and other carnivora, the peccary, hog, elk, goat and antelope, horses and cattle, ant-eater, agouti and others. It is caused in these animals by cold or by mingled rage and terror, or possibly by rage alone. Abject fear has a contrary effect. The animal then shrinks into himself as much as possible, and tries to skulk away, but if it is a case of desperation with retreat impracticable or unsafe, the hair rises. In some, as in the dog, a simple resolution to fight appears sufficient, and even when playing fight, dogs often get sufficiently in earnest to raise their hair. With them it appears to have been so much the habit that it has reached great facility.

The panniculus carnosus, or sheet muscle, which covers the body of quadrupeds directly under the skin, has been mentioned in chapter five. It is a striated muscle, and is generally subject to the purposive will. In many cases the arrectores pili are connected with the panniculus, so that the latter assists in the process of raising the hair. In such cases the raising of the hair may be, to a certain extent voluntary, but it could not be completely so, as long as the immediate connections with the individual hairs are made by unstriated muscles. In some cases the large hairs, such as whiskers,—called *vibrissæ*—are connected with the panniculus by striated muscle fibres. In such cases the movements of the separate hairs are subject to purposive control. The hedgehog (erinaceus) has voluntary control of his spines, which are connected with the panniculus, and erected by its contraction. The porcupine (hystrix) also controls the erection of his long quils—probably by the same means.

In the order of development the unstriated muscle comes first. This is shown in the embryology of the higher animals, the voluntary muscles being first formed unstriated, and afterwards becoming striped. The larvæ of some crustaceans have unstriped muscles which become striated in the fully developed animal. The striped muscles must, therefore, have become differentiated from the unstriped; and it is reasonable to conclude that where the muscles moving the hairs are unstriped, their motion is due to emotional overflow, and, like blushing, is uncontrolled by direct purpose.

But it is possible to produce emotional demonstrations from simu-

lated, or factitious emotions. Actors often "work themselves" into such a realizing sense of the part they are performing, that their demonstrations of emotions are natural, the feeling itself being the play. And the people in the audience allow themselves to sympathize with counterfeit misfortunes, and to weep over what they know, and even realize to be unreal sorrows. There is this sort of acting in the play of dogs, in which, by going through the motions of fighting, by biting, growling, and struggling, the fighting feeling is factitiously excited and unpurposive horripilation is the result. In chapter 73 it is shown how the emotional state is induced in hypnotic subjects, by causing them to perform the "expressions" or demonstrations usually following such emotional state. The machine is worked backwards, and a factitious sentiment is produced by mechanical movement. This is practically the same thing that occurs when we *see* the acting in another person, as at the theater, or when it is presented to us through the sense of hearing, by speeches and sermons, or by seeing pictures and reading books.

"Birds belonging to all the chief orders, ruffle their feathers when angry or frightened." (Darwin.) Everyone has seen a hen do this, and it has been observed of the Owl, Swan, Cassowary, Hawk, Cuckoo, Finch, Bunting, Warbler, &c. The game cock and the male Ruff elevate the feathers around the neck when they are about to fight, and sometimes the cock raises the feathers of the head. It is curious that such a detail of emotional expression should have become developed in two such widely diverging departments of animated nature as the birds and mammals. But this development is traceable to the common ancestry of both; namely, the reptiles; for certain male lizzards when fighting erect their dorsal crests, although it is thought the scales or spines are not acted on separately. When birds are endeavoring to hide or get away from an enemy instead of fighting, their feathers fall, and lie as close as possible to the body, reducing their bulk to the smallest dimensions. Birds appear to have purposive control, to some extent, of the elevation and depression of their feathers, but under the influence of sudden terror they are elevated by reflex stimulation from the brain. The erection of the neck feathers of the game cock must be involuntary, for it is said by gaming experts that such erection is a disadvantage in fighting, and so these feathers are sometimes cut off. The erection of the head feathers, too, is a sign of cowardice, so of course that must be purely emotional, as no animal would voluntarily advertise itself a coward.

Warner ingeniously and truthfully generalizes all the *effects* of forces at work in organic nature, and even inorganic nature, as the *expression* of such forces. The expansion of the mercury in a thermometer is an

expression of the force of the heat there is in it. The sensitive flame in a tube dances up and down in obedience to aerial vibrations of a certain kind. A flame of a gas jet under heavy pressure, blazing up two feet high, fell a foot at the sound of a chirp at the farther end of the room. It danced in time to a waltz played by a musical box. It kept time to the ticking of a watch, trembled and contracted at the rattling of a bunch of keys, and cowered down to almost nothing at the sound of a hiss. But it could not be moved by the vowels o, u, or the labials.[1]

The telephone, telegraph, printing press, locomotive, water-wheel, wheat roller, cotton gin, and every other tool and machine contrived by human ingenuity, is competent to be moved by some application of external force, which force continuing through the machine in modified expression in the turn of each wheel and the glide of each band, presents, in its last expression, the desired movement to which all the rest are preliminary.

Amongst natural objects the form taken by the crystal as the result of the operation of the polar forces that build it up, is a sort of expression in posture, or the position the parts are left in when the forces are through with their action; as the posture of defense, or the posture of humility, is the position a man is left in after motives of defiance or abasement have gone through him. The growth of a crystal and of any organism is an expression of the activity of forces, and we ascertain by observation the sort of forces associated with such and such expressions, and give the latter names to suit. Growth in a crystal is expressive of polar action; in an organism, of polar vital action.

CHAPTER LXXII.

DOMINANT IDEAS.

All ideas, if they ever contribute to motor action, are, for the time being, Dominant, whether the actions set up by them are upon the internal organs, as the heart, stomach, glands, &c., or the muscles of the limbs, &c. All ideas are never dominant at the same time; some very seldom are, while some are exceedingly prominent, and for a longer or shorter period, or, perhaps, for a whole lifetime give color to the most of the actions. An Idea may be defined, in this connection, to be the sensation of a relationship between two or more cerebral memories, or the composite sensation of such memories, mingled together, forming the sensation of relationship. Thus, a man has an idea that whiskey drinking is injurious. He gets it from the memory of whiskey drinking in association with a memory of misery, the association of the two in the objective environment, be-

[1] Warner's Physical Expression.

ing reflected in the cerebral organs in like relationship, thus setting up the idea. The idea becomes a *principle*, as pointed out in chapter 65, and subsequent agitations of it, in recollection, contribute their influence to various forms of motor activities, and also to new cerebral arrangements. Every body is familiar with the various incantations and hocus-pocus performances by which school boys get rid of their warts. Success depends, apparently, on the direction of the attention, involving a new direction of the secretions.

It has been mentioned that the flow of saliva may be brought on by the mere thought of food, and likewise the discharge into the stomach of gastric juice, has been caused by the sight of food. But the secretion of saliva is arrested by a strong emotion, as in the case of detection of a thief among the household servants in India by holding rice in the mouth. Tears, too, which are constantly and normally formed for the lubrication of the surface of the eyes, are increased by any sort of moderate emotional excitement,—grief, anger, joy and tenderness. But where the emotion is immoderate the secretion is checked, instead of stimulated, that is, the over stimulation of the glands and ducts, produces a violent contraction, probably something akin to a temporary local tetanus. The gastric secretion is likewise suspended by great excitement, and a sudden emotion takes away the appetite.

No secretion is more subject to the influence of emotions than that of the milk. According to Sir Astley Cooper, "The secretion of milk proceeds best in a *tranquil state of mind*, and with a cheerful temper." Then it is abundant and wholesome. But grief, anxiety, worrying, suspense, fear, terror, rage, and the like, all have an unfavorable effect; some of them stopping the secretion, others rendering it unwholesome and injurious to the infant. It may become even poisonous under extreme mental excitement. "A carpenter fell into a quarrel with a soldier billeted in his house, and was set upon by the latter with his drawn sword. The wife of the carpenter at first trembled from fear and terror, and then suddenly threw herself furiously between the combatants, wrested the sword from the soldier's hand, broke it in pieces, and threw it away. During the tumult, some neighbors came in and separated the men. While in this state of strong excitement the mother took up her child from the cradle, where it lay playing in the most perfect health, never having had a moment's illness; she gave it the breast, and in so doing, sealed its fate. In a few minutes the infant left off sucking, became restless, panted, and sank dead upon its mother's bosom. The physician who was instantly called in, found the child lying in the cradle as if asleep, and with its features undisturbed, but all his resources were fruitless. It was irrecoverably gone." A sad, cruel case happened in the Maternity Hospital, Minneapolis, in 1887. An unmar-

ried woman took refuge in the Hospital some months before her expected confinement, and had by her amiable qualities, won the good opinion of its officers and inmates. "She had made a good recovery, but when her infant was two weeks old her relatives learned of her place of refuge, and of the disgrace that had befallen her. They came to her, and so distressed her with their reproaches, that nursing her babe threw it into convulsions, from which it died in a few hours, although up to this time it had seemed perfectly healthy. This combination of troubles resulted in a shock which proved fatal to the mother."

In cases of hysteria the patient has convulsions, jerks, etc., under the conviction that she is under such control. On the other hand, they often get the notion that they cannot walk or move, when their only disability consists in the conviction that they cannot. Almost all that is necessary to the performance of the cure of many supposed cases of paralysis, is to produce a conviction in the patient that a cure is about to be effected upon the exertion of a certain effort on his part. "And thus it has been that many pseudo-miracles have been wrought on this class of patients by religious enthusiasts, and that many wonderful cures have been affected by the supposed influence of mesmerism. All that is wanted is that state of *confident anticipation* which is commonly designated as Faith"—(Carpenter). The curing of diseases by "faith," by "charms," miracles, etc., is explainable on the theory of the concentration of attention, by which there is a stimulation of normal functions or an elimination of morbid deposits. Where diseases are stimulated by terror, as they are often supposed to be in epidemics of cholera and the like, it is probable that the reverse action takes place, and that over stimulation of the blood vessels drives out the blood, as in the case of blanching or turning pale, and fainting in the presence of danger, and the stoppage of the heart, from the same cause as shown in chapter 53.

In most cases of insanity the disease is due to the excessive dominance of some idea. Nearly all the intellectual operations of our lives are performed under the influence of our dominating ideas. If the ideas are in themselves correct and sound, their excessive and untimely influence begets simply too much zeal and enthusiasm. The subject "rides a hobby," or he is a "bore," or a "crank." If the idea is wrong or unsound its excessive influence begets insanity and mania. The ideas which are thus dominant may be of a temporary character, or they may endure throughout a lifetime. In the delirium of disease all the ideas present are greatly inflamed and intensified. But it is evident that all the ideas possible to the patient are not for the time being present, that is, are not aroused or in a condition to be readily aroused. If they were, a condition of inflammation by exciting all parts alike

would simply produce intense and rapid, but not abnormal, thinking; and this is really the case in many instances of fever. But in delirium, the disease has reached a stage in which a portion of the brain cells are, through excessive stimulation, abnormally erethised, and their action being unmodified by that of the rest of the cells, the balance between different ideas is destroyed. Suggestions which happen to influence the cerebrum at such a time are apt to have an abnormal power. All sorts of sights and sounds near the bedside of the patient produce intense effects in the imagination. A case is cited in which, during an epidemic of fever in Edinburgh, many of the patients of a certain doctor seemed to show a tendency to throw themselves out of the window. Investigation showed that one patient having first made such an attempt, the doctor in question thought proper to caution the attendants upon his patients, to use extra precautions against such attempts on their part. When he gave such instructions in the *hearing* of the patients, the idea of doing the thing took possession of them, which, but for the suggestion, it might not have done.

There are many well authenticated cases of the "marking" of unborn infants through the senses and nervous system of the mother. The unborn babe is, in a certain sense, an appendage or outgrowth of the mother, and is connected with her nervous and vascular system. Anything, therefore, which affects the blood or excites the nerves of the mother is apt to affect the child. In like manner it is, that any part of the body proper, may, at any time, receive the effects of extreme emotion. Thus, "a lady who was watching her little girl at play saw a heavy window sash fall upon its hand, cutting off three of the fingures, and she was so much overcome by fright and distress as to be unable to render it any assistance. A surgeon was speedily obtained, who, having dressed the wounds, turned himself to the mother, whom he found seated, moaning, and complaining of a pain in her hand. On examination, three fingers corresponding to those injured in the child, were discovered to be swollen and inflamed, although they had ailed nothing prior to the accident. In four and twenty hours, incisions were made into them and pus evacuated. Sloughs were afterwards discharged and the wounds ultimately healed." Another case related by Dr. Tuke, is of an intelligent lady, who, passing a public institution, saw a little boy in whom she was interested, coming through the iron gate. She saw him let go the gate and allow it to swing shut with great force, and she thought it was about to strike his ankle, and crush it. Although this did not happen, she instantly experienced a severe pain in the ankle, corresponding to the one belonging to the boy, which she expected to see injured. She had difficulty in walking home, a quarter of a mile, and then she found a circle round the ankle as if it had been painted

with red currant juice, with a large spot of the same on the outer part. Next morning the whole foot was inflamed, and she was confined to her bed with it for many days.[1] The belief in witchcraft and the power of spells and incantations which have been entertained by the superstitious of both savage and civilized peoples, has always, no doubt, had much to do with actually producing the effects anticipated. And it is well known that many persons have, under the stress of vehement accusation, acknowledged themselves guilty of the most unreal and absurdly impossible crimes. Among the North American Indians, the 'medicine men, or priests, were believed to be possessed of supernatural power, and if they chose to exert it against an enemy, the victim, under the conviction that he was bewitched, would probably reject all food, and sink to death under the terror of his superstitious delusions. It is related that these medicine men sometimes tried their power upon each other in a sort of duel. Each would take a seat opposite the other, surrounded by the mysterious paraphernalia of his craft, and call upon his gods, one after another, to strike his enemy dead. Sometimes one "gathering his medicine," as it was termed, animated by a superior will, would in a severe and authoritative voice, command the other to *die!* "Straightway, the latter would drop dead, or, yielding in craven fear to a superior volition, forsake the implements of his art, and with an awful terror at his heart, creep to his lodge, refuse all nourishment, and presently perish.[2]

"Faith-cure," "Christian science" cures, and the like, depend equally upon the influence exerted through the brain upon the secretions of affected parts. Many remarkable cures have been effected by these means, and they have, by the superstitious, often been reckoned as genuine miracles. During the "age of faith" in mediæval times, such cures were doubtless more common than in this period of skepticism. A young woman, a scholar in a nunnery at Port Royal, was affected by a bad case of fistula lachrymalis, or dropsy of the lachrymal sac, in which disease the tear ducts leading into the nostrils become collapsed and functionless, and the bones themselves, in consequence, become diseased. It this case the diseased parts emitted a fetid odor and the surgeon had concluded the only remedy was cauterization. Before this was resorted to, it happened that there was exhibited in the chapel of the convent, a "Holy Thorn," and in a procession in its honor in which the girl took part, upon the recommendation of the nuns, she applied the relic to her eye as she passed before the altar, at the same time praying for relief. A change for the better began at once, and within a short time a cure was effected, the doctor having the good sense to let well enough alone.

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[1] See Carpenter's Mental Physiology. [2] Brinton's Myths of the New World, 277.

This cure, the reality of which was established by an examination by a civil court, was set down by the faithful as nothing less than a miracle.

The beneficial effects of many patent medicines, and of other appliances and modes of treatment, such as "touching" by the king for scrofula, carrying a buckeye in the pocket for piles, or a potato for rheumatism, depend upon the same principle. About the end of the last century, Dr. Elisha Perkins, of Connecticut, invented the "metallic tractors," which consisted of a couple of rods of different metals, the points of which were drawn over the affected parts. It was thought they produced some sort of galvanic effect, and at any rate they appeared to effect cures, of which *hundreds of thousands of cases* were reported, chiefly of pains and local inflammations. It was found, however, that wooden points painted to resemble the metallic ones answered the same purpose, and that, therefore, the cures were performed through the brain and not by galvanism. As soon as that idea became prevalent the cures ceased, and the bubble exploded.

The many disastrous failures of the faith-cure and Christian science people, show that there is a limit to the influence of the cerebrum upon the secretions, which cannot be ignored with impunity. Among the islanders of the Pacific, the chief restraint from any conduct which they regard as criminal, immoral or even improper, is in their dread of the tabu or tapu. This means the jurisdiction, guardianship or ban, of some supernatural agency. Thus, a chief may put a tabu on a certain fishing ground, which prohibits any one from fishing there. A man may put a tabu on his yam patch or cocoa grove, which prohibits poaching. The habits of life to minute particulars are prescribed by hereditary tabu. It is, in fact, fashion crystallized into superstition. The penalties for broken tabu are supernaturally inflicted diseases. If one eats tabu fish, he is wasted by a slow disease; if he eats tabu cocoanuts or bread-fruit, he is acutely sick next day, and in two days he will die unless cured by an application of the leaves of the tree from which the fruit was stolen. This obviously involves confession of the crime, and operates as a detective device. Of course the penalties are purely self-inflicted and arise from such control over the vegetative viscera as is possessed by the organs of the internal senses. Let the victim be convinced that he has incurred such and such penalty, and it is exceedingly apt to occur just that way. A story is related by Dr. Campbell, of a certain New Zealand girl who was foolishly told that a yam she had eaten was tabu. She was taken sick at once and died in two days. Trial by ordeal, as practiced among the ancients, of which modern duelling is a survival, was founded upon the same principle. One who felt himself in the right and supported by supernatural assistance, was nerved to extraordinary force and endurance, while one who knew himself in the wrong was in

the same degree depressed and emasculated. (See Numbers 5 : 21; Matt. 17 : 20; Matt. 9 : 22; Luke 17 : 19 and 18 : 42.)

The following is taken from a report in the Evening Tribune, of a session of the Baptist Missionary Conference held at Minneapolis, Feb. 15, 1892: "Dr. J. C. Clough, the Telugu missionary, followed in an informal talk, in which he related a peculiar incident. He once called on a native magistrate who would not allow the native converts to live in peace. The magistrate refused to treat the natives with fairness, and Dr. Clough invoked the wrath of God, telling him that his life would be required in two months. 'Two days from that talk,' said Dr. Clough, 'that magistrate was attacked with a huge carbuncle on his neck, and two months from that day his body was being cremated.'" The presumption intended to be conveyed by the above, appears to be that the chief was "removed" by supernatural agency, upon the recommendation of the missionary. But perhaps the result might have been a consequence of the superstitious terror of the magistrate himself. In either case it was a mode of "working off" an objectionable party, very superior to most of the methods in common use.

A great many ideas are handed down from one generation to another, which are supposed to embody the wisdom gained by the experience and observation of the ancients. Many of these ideas exercise a dominating influence over our actions and lives, and often continue to do so even after they are proved to be wrong, because the average man finds it easier to take the consequences of a wrong idea, if it did not kill his father, than to pull up the deep-rooted habits of hereditary cerebral organs.

Our habits of belief give us peculiar conditions of receptivity. We easily credit those statements which do not contradict what we already believe in. But if a new fact is inconsistent with our established opinions, it is hard to be believed. (See chapter 67.) When the belief in miracles was current, the most marvelous tales were accepted with little inquiry. Tertullian said, "Credo quia impossibile est." "I believe (it) because it is impossible." That is, since miracles are perfectly credible, it is easier to account for an unusual event as a miracle than to disprove it as an event. If the thing is impossible as a natural event, it is none the less credible, because it is then a miracle. Belief in miracles and the theological dogmas of the Trinity, of the fall of man, of baptism, of the resurrection, of heaven and hell, &c., together with most of the moral precepts, have come down to us as heirlooms from our ancestors. They exercise a dominating influence upon us; and if anyone rebels, he inaugurates a civil war amongst his internal senses, which may be long in reaching a satisfactory peace.

Among the ancients, the opinion was more or less prevalent that women were essentially depraved. This is exemplified in the story of

Adam and Eve. During the early centuries of the Christian era, the opinion was common to both Pagans and Christians. Cato said if there were no women, men would hold converse with the Gods. Cicero's ideas were about the same. Chrysostom, and other Christian fathers, believed in the depravity of women, their malignity, inconceivable subtlety, frivolity, and unconquerably evil propensities. This led to celibacy as the only possible chance for men to be holy, and it also led to the habit of ascribing the crime of witchcraft, of which there were many forms, almost entirely to women. (See Lecky's Rationalism.)

The belief in witchcraft was implicitly entertained by all the world, both Pagan and Christian, from time immemorial, until a century or so ago, and is yet held by a few even in Christian lands. Hundreds of thousands of people were condemned to death for this crime during the middle ages in Europe, many of them upon their own confession. In these days of free inquiry and discussion, we have no conception of the tenacity with which the traditional ideas of this sort grasped and bound our ancestors. Such men as John Wesley and Dr. Adam Clark believed in witchcraft, and the former inveighed against the growing disbelief in it, as an incipient form of infidelity.

When a man is born into the world, he finds everything prepared for him. The ideas of the past are worked out and expressed in the forms of everything he sees. From these forms the ideas are reflected into his brain, and the representative standard organs are there built up in close imitation of those of the preceding generation. His education consists chiefly in becoming thus placed in touch with the ideas that have been thought out before his time. He must adopt the language of the community, their style of dress, their manners and deportment, their tools, utensils and appliances, their money, weights and measures. He must conform to the established laws and usages in regard to property and trade, the magistracy and the courts, his social and domestic relations, his courtship, marriage and divorce. He is almost certain to acquiesce in the religious opinions of those nearest to him, and to imbibe their political bias. He is necessarily a patriot, and whether he be an inhabitant of torrid Africa, or frigid Alaska, or desolate Patagonia, or fertile India, he thinks his own land the most delightful, and his own people the best. All this is because he is made of plastic protoplasm, which is kneaded and moulded like dough by the influences of his surroundings, then formed and stamped with the monogram of his environment, and finally baked into the statutory loaf of precisely sixteen ounces, like all the rest. These traditional and hereditary influences which bind us to the past, necessarily resist change and progress. But the investigations of science bring to view new facts, some of which contradict the notions upon which some of the hereditary ideas are

founded, and gradually subvert such ideas and change the actions to which they lead; others show new relations and possibilities of action never before dreamed of. The invention of the compass enabled mariners to sail out of sight of land, which before they were afraid to do. The invention of the telescope led to the proof that the world was not the center of the universe, and thus undermined the notion of its relative importance, and consequently of the importance of the human race, its most valuable appurtenance. Thus, the dominant ideas are subject to slow evolution and modification by the natural forces of the environment, just as the Gods are subject to the Fates.

The dominance of a general idea often leads to individual delusion. When witchcraft was a common belief, individuals were often found to fancy themselves bewitched, while it was no uncommon thing for a woman to confess herself a witch. In times of religious excitement, individuals often imagined themselves to receive impressions from a supernatural agency, when in reality they are only under the influence of a dominant idea, become highly personal and emotional.

When dominant ideas become emotional, they may become epidemic, and affect large numbers of persons belonging to a particular community or society. There are many examples of emotional epidemics arising most frequently from religious excitement, in which the excited emotions have found expression in convulsions, dancing, and various phantastic physical performances. The "dancing plague" is a form of convulsion something like St. Vitus' dance, which has occurred in various parts of the world, under different names, as Tarantismus in Southern Italy and Northern Africa, and Tigretier in Abyssinia. In Scotland they have had what they call Leaping Ague, which results from an "irresistible propensity to dance, tumble, and move about in a fantastic manner" with extraordinary energy. Almost all nervous diseases are more or less due to an idea, which is proved by the fact that they can often be cured by a counteracting idea. Thus it is related that a factory girl in a factory in Lancashire was thrown into fits by a mischievous fellow who put a mouse down inside of her clothing. The sight of the spasms caused an epidemic which spread among the other girls, till scores of them had fits day after day. They got a notion that they were caused by the emanations from a bale of cotton. This was shown to be a mere whim. The cure was finally effected by shocks of electricity accompanied by the assurance of its efficacy on the part of the medical man. It was simply diversion from a dominant idea and substitution of another for it.

Fits of hysteria once got to be epidemic among the Irish girls in a hospital at Bristol, and were cured by threats of a shower bath to all that indulged them. In a certain nunnery in Europe, one of the nuns got

to mewing like a cat; soon the rest took it up and it became an epidemic. In another nunnery one began to bite, and the rest took up that trick. In one of these instances the epidemic spread into other nunneries through Germany, suggested merely by the account of it which was carried from one to another. It was cured by threats of punishment. Boerhaave cured epidemic fits in an orphan asylum in Holland by heating a poker and threatening to burn the first girl who had a fit. At one time in Scotland, they got fits in the churches, particularly in Shetland. The minister in one case stopped them by threatening to duck in the horse pond anyone who yielded to them. The convulsionnaires of St. Medard in the last century were cured by being beaten with sticks. Witchcraft, which had been a chronic delusion for several thousand years, broke out in the latter part of the 17th century into an epidemic, the violence of which, by causing a re-examination of the idea in the light rationalism, finally destroyed its domination.

In the early part of this century, in Tennesse and Southern Kentucky, there occurred a series of remarkable epidemics, in connection with revivals of religious excitement. At the meetings at which there were sometimes several thousand people, there occurred various manifestations, which were called the Jerking, the Rolling, the Falling, the Dancing, and the Barking exercises, also Visions and Trances. Almost any movement made by one seemed to act as suggestions to others, and thus large numbers would engage in the most absurd pranks. One lusty hunter started on a run to "chase the devil." He was immediately followed by numbers of others. Then the devil was imagined to climb a tree, and some climbed after him. This they called "treeing the devil." In the Jerking exercises, a multitude were often caused to jerk their heads and other parts of the body with great violence, the long hair of the women snapping back and forth like whip-lashes. At one time it was estimated that 3,000 people had the Falling exercise, and were on the ground at one time.

The "force of suggestion" acts as a strong motive in shaping the ideas and actions of others. We see this in the tendency to imitate people who stutter, a tendency which it often requires strong counter motives to resist.

The following story from Abercrombie shows how a false perception may be "catching." No doubt it was the imagination of *one* communicated to the rest who were in a state of like superstitious preparation. "A whole ship's company was thrown into the utmost consternation by the apparition of a cook who had died a few days before. He was distinctly seen walking ahead of the ship with a peculiar gait by which he was distinguished when alive through having one of his legs shorter that the other. On steering the ship towards the object it was found to be a

piece of floating wreck." Such delusions are common. They originate in the cerebrum, while pure *illusions* are probably due to improper reactions of the sensory ganglia.

But suggestion also plays an important part in all the ordinary actions of life, as in fashions, dress, manners, modes of thought, language, &c. If a newsboy enters a crowded street car it may happen that he will run the gauntlet between the long seats without selling a paper. If, as he is about to get off, a passenger calls him back and buys a paper, the act becomes a suggestion, and probably half a dozen others will do the same. In signing a subscription paper or a petition, the subscribers are often moved by nothing else than the names already signed.

Another phenomenon of kindred sort is the automatic and unconscious conversion of a suggestion into motor action in our own muscles. This is called Expectant Attention. If a person will hold, attached to his thumb, a button suspended by a string, in such a position that its oscillations would make it strike a glass tumbler, he will find that he can not hold it quite still, even by the greatest effort. If he is not too positive and skeptical, an assurance or expectation that the button will strike the hour of the day will very likely be realized. The muscles will be influenced by the conviction, and perform the oscillations through an unconscious will. The number struck will tally with the performer's idea of the time of day. The motions of the hand are governed by this idea. That is, the will is insensibly dominated by that idea, and the further idea that this number will be struck upon the glass. There is nothing violent in this theory; it corresponds with what is ascertained to be the operation of the will in other examples. The great majority of our actions are miscalled involuntary, because they are performed without arousing consciousness. But, after making due allowance for those which are stimulated by the lower parts of the spinal axis, and the sensory ganglia, in what are called reflex and consensual actions, there are still a good many in the stimulation of which the cerebral ideas form a constituent element. If the operator should close his eyes, so as not to *see* whether the vibrations were *regular* or not, they would become irregular. In short, the result will accord with the idea of the operator. The same explanation properly accounts for the practice with the divining-rod, an instrument made of a forked hazel stick, by which subterranean currents of water, and deposits of metal, are pretended to be discovered. If the party using it has faith, the rod will point to the place where he expects to find the deposits he seeks, or if he has no opinion on that score, after his muscles have, for some time, been held in one positon, they will begin to move spasmodically, whereupon the operator, perceiving the twitching of the rod, has his expectation raised that the performance is about to begin, which expectation becomes, of

itself, an element in the development of further movements in the same direction.

This divining-rod has been used from ancient times for the purpose of giving answers to questions, asked of the supposed supernatural powers, just as planchette and the tipping tables have been used during the present generation. The motive power is in the muscles of the persons engaged, and it is directed by an unconscious will, the chief element of which is the expectant idea. "The demonstration that the table really is moved by the hands placed upon it, notwithstanding the positive conviction of the performers to the contrary, was first afforded by the very ingenious indicator devised by Prof. Faraday, which showed that lateral pressure is *always* exercised, however unconsciously, before the movement commences, and if, by keeping their eyes upon the index, the performers check the first tendency to exert such pressure, the table never gives the least sign of movement." (Carpenter.) Prof. Faraday agreed with Carpenter as to the cause of the movement. The explanation here given is consistent with the fact that the answers are often unexpected; because there are in every brain a vast number of facts unremembered until brought out by some appropriate suggestion. In the unconscious cerebration of sleep, we are often startled by most unexpected results. Yet an examination will show that the elements of every dream are already in the brain, and the action which has gone on there consists simply of their rearrangement.

A greater or less degree of abstraction, reverie or preoccupation appears to contribute to this process, especially to that part of it in which the result of the motor will is transferred to its expressive muscular action without arousing consciousness. This is generally attained by the operators by a period of waiting in stillness, by monotonous music, &c. Carpenter quotes from Rev. R. W. Dibdin's lecture on table turning, the following anecdote: A gentleman was talking (as supposed) with the spirit of Young, the author of Night Thoughts, and upon requesting the spirit to quote a line of his poetry, the table rapped out, "Man was not made to question, but adore." Being asked if the line was in Night Thoughts, the table replied, "No." "Where is it then?" The reply was, "Job." The Gentleman was not aware that he had ever seen the line before, but he had. It is in a paraphrase on Job and was printed at the end of Night Thoughts in a copy which he possessed and had read and "forgotten."

The insensible influence exerted upon the muscles by ideas, allows the phenomenon of *muscle reading.* Suppose X hides a small object, and B, a muscle reader, who calls himself a *mind reader*, undertakes to find it. B takes the hand of X and they start together. The muscles of X, under the insensible influence of his memory organs, are inclined to the

very slightest and almost imperceptible degree, to lead the way and turn the corners necessary to reach the place. B by yielding to these delicate .mpulses really follows X instead of leading him as he pretends to do. If X is posted and is on his guard, the element of expectation will become deranged and the experiment fail, unless B *is* a mind reader as well as a muscle reader.

CHAPTER LXXIII.

REVERIE, SOMNAMBULISM, HYPNOTISM, SLEEP.

Attention appears to be the first stage of mental abstraction, of which *reverie*, absence of mind, *somnambulism and hypnotism* are further and more intense states.

The acuteness of sensations depends greatly on the attention they receive. No sensation is produced in sleep by ordinary *impressions*, and it is the same when the attention is already engaged on something else. On the other hand, impressions which are felt in a slight degree are greatly intensified when the attention is directed to them; "thus, everyone knows how much a slight itching of some part of the surface may be magnified by the direction of the thoughts to it, whilst as soon as they are forced by some stronger impression into another channel, the irritation is no longer felt." In viewing a landscape we get no idea of details unless the attention is directed successively to each one. If we attempt to sit still by thinking to do so, and directing attention to it, we shall find it difficult, but can easily be perfectly still for a long time when the attention is held by an interesting discourse or spectacle.

Habit has much to do with the intensity of sensations. The general law is that "sensations *not attended* to are blunted by frequent repetition," but if attended to their effectiveness is increased by repetition. The direction of the attention is the direction of the blood supply, and when a stimulation comes, it directs the blood to the part of the brain stimulated. If the stimulation is an undesirable one, it is, in part, neutralized or resisted by the stimuli representing this undesirability, so that the attention and blood supply are reduced. Subsequent stimulations of the same sort, automatically arouse the antagonistic and neutralizing elements which are now in the nature of associated stimuli, and act upon the principle of automatic control set forth in chapter 66. The oftener the process is repeated, the more complete is the neutralization of each other by the antagonistical stimuli, and the less sensation and attention they arouse. On the other hand, if the stimulations do not antagonize the organs and conditions already formed, but agree, they will be reinforced by them, and attention intensified by repetition.

Where there is no special antagonism against an incoming stimulus, unless it be overpowering, it may fail of attention by reason of the preoccupation of the brain. It is the degree of change that constitutes the intensity of the sensation. If one hand be held in hot and the other in cold water, and then both suddenly transferred to tepid water, it will feel warm to one and cool to the other. We get used to noises, or smells, or degrees of light or heat, which startle a person not accustomed to them. Same is true of poisons and stimulants. A telegraph operator will go to sleep alongside of his ticking instrument, and remain undisturbed till his own "call" is sounded, which, to uneducated ears, is indistinguishable from the rest of the clatter of the instrument.

While we are assailed by an infinite number of stimulations, there is not capacity in our small machinery to give them all attention. The greater part of them glance off without appreciable effect, and a great many that would have an influence are neutralized by others of contrary qualities. Those stimuli which we have already assimilated, and which have made us what we are, determine what new ones shall receive attention. What we are, determines what we shall be. There are different degrees and modes of attention, as mentioned in the beginning.

Reverie is a state into which most persons are more or less liable to fall. It is a condition in which the cerebral actions are not under the control of any dominant idea, but rather of a particular class and species of ideas, and in which each memory or idea is either directly or indirectly a suggesting stimulus for the next. In this respect it is like dreaming, and such cerebral actions are properly called waking dreams. The persons to whom this state is most common are those of an emotional and imaginative nature. And their thoughts are more apt to embrace subjects in which ideas of that sort are involved. While under such general influence the sort of external impressions most attended to are those which appeal to the esthetic and sentimental feelings, the grand and poetic in nature and art, &c.

Abstraction, or "*Absence* of *Mind*," is usually reckoned a more intense state of reverie. Almost everybody is more or less liable to it, but to some persons it is easily habitual. When persons are in a profound state of abstraction they are so engrossed by the ideas towards which their attention is directed, that they are almost wholly oblivious to external impressions, and the perceptions they do obtain are apt to be distorted and false. The sort of ideas most common in states of abstraction, are of an intellectual and abstract nature, devoid, in general, of emotional or personal elements. There are persons so addicted to this habit that only the most forcible impressions of the senses can disturb the tenor of their thoughts.

Remarkable and amusing stories are told of persons to whom abstrac-

tion is a natural habit. Prof. Dr. Robert Hamilton, of Aberdeen, was one of these. He was an author of numerous works, written in a clear, accurate, and scientific style, but the preoccupation of his attention was so engrossing, that sense impressions were only half perceived by him. If he met his wife in the street he pulled off his hat and "apologized for not having the pleasure of her acquaintance; went to his classes in the college on the dark mornings with one of her white stockings on the one leg, and one of his own black ones on the other; often spent the whole time of the meeting in moving from the table the hats of the students which they as constantly returned; sometimes invited them to call on him, and then fined them for coming to insult him. He would run against a cow in the road, beg her pardon, call her 'madam,' and hope she was not hurt. At other times he would run against posts and chide them for not getting out of his way." These performances were bad enough, but Carpenter relates a worse one.

A story is told of a Philosopher who was addicted to the habit of abstract meditations, that once being interrupted by a servant who rushed in to tell him the house was on fire, coolly replied: "Go and tell your mistress; you know that I never interfere in domestic matters!"

A story of the mathematician Gauss, is still worse. His wife, to whom he was deeply attached, was very sick. He was engaged in some abstruse calculations when the servant came to tell him his wife was worse and wanted him. "I will come presently," he said with his lips, but his brain kept right on with his figures. After a while the servant came again, his wife was worse; same reply, same effect. The servant at last came to announce that his wife was dying, and if he did not come at once he would never see her alive again. He raised his head and calmly answered, "Tell her to wait till I come." This reply he had often, no doubt, sent her before when his presence was required, and now it was made automatically and with little or no consciousness of the import of the message he had received.

Somnambulism is a state in which a part of the cerebral cells are awake while others are not, so that the voluntary acts are one-sided and under the undue domination of some idea or class of ideas to the exclusion of others, which if they were awake and active would give a different and more rational and consistent direction to the thoughts and actions.

The actions of the Somnambule, under the direction of a governing idea, are what might be called eccentric, since they are dictated by only a part of the ideas which should enter into the construction of the motor will. When external impressions and suggestions are the governing force as they sometimes are, these stimuli are not co-ordinated and balanced

with the memories of others, but exercise an unlimited and consequently undue influence, and produce eccentric acts and distorted ideas. The actions are more directly reflex than in the ordinary state.

In somnambulism the actions and thoughts are not connected with those of the waking state by memory, and after a person is roused from this state he remembers nothing of what has taken place. But upon entering the state a second time, it appears that in many cases, at least, the actions which took place during the continuance of the first occasion are remembered and form a new state of consciousness separate from the waking one.

"A young lady was formerly known to the writer" (Carpenter) "who, when at school, frequently began to talk after having been asleep an hour or two. Her ideas almost always ran upon the events of the previous day, and if encouraged by leading questions addressed to her she would give a very distinct and coherent account of them, frequently disclosing her own peccadillos and those of her school fellows and expressing great penitence for the former whilst she seemed to hesitate about making known the latter." In ordinary sleep she could be wakened by a loud noise but not when she was in the sleep-talking state. If she were addressed on matters foreign to the present subject, she paid no attention to them, but could be *gradually* led from one subject to another by adroit leading questions. Sometimes, generally in fact, the attention of the somnambulist is fixed so exclusively upon the ideas automatically formed in his own internal sense organs that his train of thought is not disturbed by external impressions, so that he may not be conscious of anything said to him. If, however, something is said which is in the line of his thoughts, it may have an influence in forming and modifying the train of thought, and a bystander may thus, by timely suggestions and leading questions and remarks, give direction to the sleeper's flow of ideas. But if the external impressions are of a nature foreign to the subject of the thoughts of the sleeper or of his dominant idea, they are lost and no attention is paid to them. Remarkable performances are related of somnambulists who have fallen into the state while under the influence of a strong dominant idea. Sometimes upon waking, no recollection whatever of the thoughts or actions which took place during the sleep remain, but more commonly there is a recollection of the occurrences as if they were dreams. "The first degree of somnambulism generally shows itself by a propensity to talk during sleep; the person giving a full and connected account of what passes before him in dreams, and often revealing his own secrets or those of friends. Walking during sleep is the next degree and that from which the affection derives its name. The individual gets out of bed; dresses himself; if not prevented goes out of doors,

frequently walks over dangerous places in safety, sometimes escapes by a window, and gets to the roof of a house; after a considerable interval, returns and goes to bed; and all that has passed conveys to his mind merely the impression of a dream. A young nobleman mentioned by Horstius, living in the citadel of Breslau, was observed by his brother, who occupied the same room, to rise in his sleep, wrap himself in a cloak, and escape by a window to the roof of the building. He there tore in pieces a magpie's nest, wrapped the young birds in his cloak, returned to his apartment and went to bed. In the morning he mentioned the circumstances as having occurred in a dream and could not be persuaded that there had been anything more than a dream, till he was shown the magpies in his cloak. Dr. Pritchard mentions a man who rose in his sleep, dressed himself, saddled his horse, and rode to the place of a market which he was in the habit of attending once a week; and Martinet mentions a man who was accustomed to rise in his sleep and pursue his business as a saddler. There are many instances on record of persons composing during a state of somnambulism, as of boys rising in their sleep and finishing their tasks which they had left incomplete. A gentleman at one of the English Universities had been very intent during the day in the composition of some verses, which he had not been able to complete; during the following night he rose in his sleep and finished his composition, then expressed great exultation and returned to bed." [1]

The Electro-Biological State or Hypnotism, is a state of *induced* or artificial somnambulism in which the trend of the ideas of the "subject" is directed by the suggestions of external stimuli. A person may enter this state for a pre-conceived purpose, and this purpose will remain as the governing stimulus or dominant idea of the thoughts during the continuance of the condition.

Hypnotism and mesmerism are nothing more than intensified varieties of induced or artificial abstraction. In the less intense form the subject remembers what has taken place, after he returns to his usual condition, and his actions, while in the artificial condition, are connected to a certain extent with his ordinary ideas. But these have not their usual weight and influence because almost the whole attention of the subject is concentrated upon the dominant idea so that *it* has more power in forming the will and in controlling the direction of the thoughts while attention is withheld from those antagonizing ideas which would tend to reduce its influence. The state may be defined, in short, as abstraction in favor of a definite idea or of a very circumscribed class of ideas, as reverie and absence of mind may be regarded as abstractions in favor of a definite general class of ideas, and each of them is only a condition

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[1] Abercrombie, Intellectual Powers 238.

involving a prolonged and more exclusive concentration of the same *attention* which in our ordinary state is directed temporarily and by turns to every sensation, purpose, and action of life. It is often remarked that we cannot do or think of two things at once. This is only a popular recognition of the fact, that attention is necessarily exclusive, and that when it is engrossed by one stimulus, the others are in abeyance and fail for the time of producing their effect. In ordinary life we are surrounded and assailed by a multitude of sensory impressions and suggestive ideas projected upon us from without. The one possessing the greatest tension will first control our movements, and the moment its tension becomes reduced below that of some other one in waiting, that one, No. 2, will control till *its* tension is reduced, and so on.

We are also assailed by ideas from within, constructed in the cerebrum from perceptions of former sensations. These also may at any time become stimuli and in their turn absorb the attention.

That person is the most wide-awake, versatile, and comprehensive who is susceptible to the impact of the greatest number and variety of these stimuli. But by reason of inherited peculiarities, strengthened or modified by the habits put upon us by our environment, all of us have become more susceptible to the influence of some stimuli than to that of others, so that in the presence of these we are apt to be, to a great extent, oblivious of the existence of others. That is to say, we are in a state of chronic *abstraction* as against those stimuli which fail to draw our attention.

For obvious reasons we never know what these are unless some one tells us. In any community all the people are exposed to practically the same external stimuli, and by their social habit of reminding each other of those which are liable to neglect some and to impress others too strongly, the tendency is to the formation of communities in which the individual components are very much alike, and the stimulating agencies, both external and internal, which engage their attention and regulate their actions, are practically the same for all. And likewise those stimuli which are habitually ignored and neglected are practically the same for all. And it is obviously due to this, that we are in a condition of practical oblivion of the fact that we are all of us in a state of *abstraction* as to the stimuli which in numbers, and doubtless importance, greatly exceed the stimuli of which we ever become conscious.

The smaller the number of stimuli by which we are liable to be influenced, the more concentrated and intense is the stimulation. Those further stages of abstraction which go under the names of reverie, absence of mind, biology, hypnotism, somnambulism, and dreaming, simply represent the condition after further reductions in the number of stimuli; and they exhibit their increased concentration and intensity. They do not involve any new principle whatever.

When experiments were first made in Electro-Biology and Mesmerism, an operator was supposed to be necessary in order to produce the mesmeric state by imparting to the subject some of his magnetism. This magnetic influence was supposed to be transferred to the subject by means of "passes," or downward stroking of the hands over the head and breast, or arms, or down the back of the neck and shoulders. After a subject had been in the biologized state a few times, it came to him much more easily, and it was found that passes at a few feet distance, had the desired effect. Later, it was found that a subject could be operated upon at a distance, on certain conditions. M. Bertrand appears to have been the first to discover these conditions. He attempted to mesmerize a lady upon whom he had often operated, by sending to her a letter which he had magnetized by the usual passes. This he requested a friend to place upon her stomach, and report results. The lady went into the usual mesmeric or hypnotic state the same as if the operator had been present. M. Bertrand then tried the experiment of sending her a letter which he pretended he had magnetized, but in reality had not. The effect was still the same, the lady readily dropping off into the mesmeric state. He now got a friend to write a letter for him, imitating his handwriting. This scheme also succeeded the same as the others. These experiments were transacted over a distance of one hundred French leagues. Other experimenters obtained like results. Dr. Elliotson put one of his subjects into the mesmeric state by telling her that he would mesmerize her from the next room. He seated her near the door, which he closed after going into the next room; but he made no passes, and even went on into a third room, paying the subject no attention. She fell into the desired state, however, all the same. Other experiments showed that good subjects who could be "magnetized" in two or three minutes, when they knew that the experiment was being made, were not affected at all when the operator made his passes, and exerted his "will power" behind a door or screen without letting the subject know what he was doing. It was thus shown that the effect produced by the operator was purely imaginary, and if the imagination could be got to work without the operator, the effect would be just the same. The concentration of the attention so as to induce the intense state of it, called hypnotism or mesmerism, is all that is required, and this concentration can be effected by the subject himself. Mr. Braid experimented with a gentleman of high literary and scientific abilities, who possessed an unusual power of concentration of the attention, and who needed only to place his hand upon the table and fix his attention on it for half a minute in order to place himself in a condition to be controlled. Mr. Braid then positively assuring him he could not remove his hand, he was entirely unable to do it.

When it was at length discovered that the only principle involved in the production of hypnotism is the concentration of the attention, it became evident that the "subject" could induce it himself, and a second party is not essential. Self-induced hypnotism is usually practiced for a purpose, and the actions of the subject while in the artificial state, accord with this preconceived purpose, which acts as the dominant idea for the time being, and directs the course of the cerebral activities. A person hypnotized has his powers much intensified and concentrated, and as a speaker or writer can usually exceed his waking performances.

The number of persons who are susceptible to the states of extraordinary and induced abstraction is limited, not more than one in twenty being a suitable biological subject; yet no doubt the faculty of abstraction may be cultivated to some extent by everyone. The essential part of the process is simply the fixation of the attention upon some one idea. In the biological experiments this is done in the following manner: The operator gives the subject a coin or some other bright object upon which to fix his steadfast gaze, at the same time assuring him that after a certain length of time, he will become "magnetized," or "biologized," and will be under the entire control of the operator. The object of concentrating the gaze upon the coin is to abstract the attention from all other external impressions, and also by its monotony to put to sleep the ordinary automatic activities of the cerebrum. Most of those trying the experiment fall asleep all over in the natural way; but as above stated, about one in twenty will remain awake as to *one idea*, that idea being the one associated with the sensory act of gazing upon the coin. If now the operator assures this subject that he is duly "magnetized" and under his control, the assertion is to the subject of the same value as if it were a conviction of his own intellect, arrived at in the natural way. His *will* is not laid aside—if it were he could not move a muscle, but the elements which usually enter into the composition of his will, are so far asleep that they do not take part in cerebral actions, unless called up by the suggestions of the operator and this adventitious conviction confirmed by the suggestions of the operator under it, constitutes the principal element of the will and remains uncontradicted, unbalanced and unlimited by the ordinary perceptions and ideas of the subject, as it would be if they were awake. This sleep may be of different degrees of profoundness. The *perceptions*, for example, may or may not be involved. If they are involved, their power of classifying sensory impressions is in abeyance, and such classification is now in the power of the suggestion of the operator. Thus, if he says vinegar is water, or a man is a cow, it will appear as truth to the subject, the assurance by the operator, delivered in a positive manner, making a stronger impression than that obtained through the senses. But it

often happens that the perceptions are not sufficiently dulled to be duped by the declaration of the operator, or some of them are while others are not. Thus the assurance of the operator may deceive the perception of taste when it is unable to deceive that of sight, or vice versa, etc. As long as there is any remnant of the dominant idea, the operator can use it to build upon, and as it often happens that the cerebral memories of the subject begin to awaken and consequently to counteract the influence of the dominant idea, the operator can generally reinforce the latter and maintain control by repeated and emphatic assertions which serve to convince the subject that he cannot successfully resist; that is, he brings back the attention which was beginning to wander off. The most remarkable detail of this phenomenon is what is styled the control of the memory of the subject by the operator. "The subject is assured that he cannot remember the most familiar thing, his own name for example; and he is prevented from doing so, not by the will of the operator, but by that conviction of the impossibility of" doing it, which by absorbing the attention, diverts it from starting the cerebral process necessary to the reproduction of the memory. The abolition of the conviction of personal identity is one of the strange phases possible under this control of the memory. The subject being assured that he is Mr. Smith instead of Mr. Brown is absolutely unable to recall enough of the memories of his own life to identify himself and contradict the conviction of the dominant idea. Here, as in the other cases, it is not possible for the subject to disengage enough attention from the dominant idea to restimulate the memory organs which would establish his identity. On the contrary the conviction that he is Mr. Smith may work itself out in actions and expressions, and he will begin to talk and smirk and pose as he has seen Smith do.

The hypnotic subject can be made to fall into ordinary sleep by assurances and orders to that effect from the operator. Moreover, if the time be set for the subject to awaken again spontaneously, he will be very likely to do it. Evidently, in such case, the conditions of natural sleep are artificially produced. Some persons naturally go to sleep the moment they are ready. All they have to do is to undress and get into bed at the proper hour, and within a very few minutes they are asleep. The expectation of sleep, and the withdrawal of attention from all objects of thought, speedily reduces the blood supply, and puts the brain in the necessary condition. The same principle governs the induction of sleep when the subject is in the hypnotic state, only the conditions are intensified. Again, the subject may be enjoined to sleep until the operator gives some certain signal for his waking. For example, a subject is ordered to sleep till his name is called. He may be tickled or shaken, and loud noises sounded in his ears without effect, but he will

awaken if the agreed signal be given even in a low tone. This is often paralleled in natural sleep, the sleeper oblivious to all sorts of loud noises, is easily aroused by the mention of his name, or the giving of an agreed signal. It seems that the avenues from the external senses to the cerebral organs, are all closed except one, the one upon which the expected stimulus is to come.

The several stages of the hypnotic state are, by Liebault, reduced to six, as follows :[1]

(1) Is scarcely sleep, mere drowsiness ; patient wakes as soon as operator's influence ceases.

(2) Eyes are closed; hears everything said; does not wake speedily; is in "hypotaxic" or charmed condition, or suggestive catalepsy. The arm placed in position is rigid if operator so dictates. The patient in this stage often thinks he has not been asleep, because he remembers everything.

(3) Sensibility to pain nearly abolished when the operator so assures the patient ; automatic movements started, cannot be stopped by patient.

(4) Patient hears nothing except what the operator says ; he may be transferred to another operator.

(5) Forgetfulness not quite complete, has confused recollection of some things. Patient can be made cataleptic and totally insensible to pain, and experience hallucinations and illusions of the senses. This is the stage of light somnambulism.

(6) Total amnesia ; no subsequent memory whatever of what takes place. Nevertheless the subject can hear and obey suggestions very readily. This is the grade of deep somnambulism. In some cases there is scarcely any suggestibility, all the senses being in abeyance.

The effects of suggestion made during the hypnotic condition endure for a time after the subject wakes up, varying from a few minutes to hours or even days. During this time it is felt by the subject as a strong impulse to action. "For example a good somnambulist is hypnotized, and told that on awaking he will commit a certain act, that he must commit it, and cannot offer any resistance to his desire to commit it. Accordingly, when he awakes he executes the suggestion which has been insinuated into his mind, either literally or with some slight modification, and not having any recollection of what has been told him, believes that his act is spontaneous. These cases afford the best illustration I know of the relativity of our freedom of will and of the truth of Spinoza's saying that our consciousness of free will is but ignorance of the causes of our acts. If the act which has been suggested is one which might readily be committed spontaneously, the subject makes no comment upon it. If, however, he has been told to do something ridic-

[1] Dr. C. A. Herter, Pop. Science Mo., Oct. 1888.

ulous he is usually a little ashamed of his act, and looks silly and embarassed, or if asked why he did such a foolish thing he invents a justification of some kind, and these excuses are often exceedingly amusing."

Binet and Fere appear to conclude from their experiments, that the suggestion made to the subject during his hypnotic state, operates as a strong impulse in the formation of a will. They found that it might endure for some days after the subject was aroused. The impulse no doubt stands to the subject the same as a standard organ, or principle, which has been deliberately thought out and constructed from foregoing stimulations. The impulse of the principle remains after the stimulations which constructed it are forgotten. So it is that the suggestion in hypnotism is forgotten, while the resulting conviction remains to act as an impulse. Obviously it is possible to cause the most serious crimes to be committed by hypnotic subjects who remember nothing of the suggestion under which they act, and think they are free and the act their own. This was tested by M. Liegeois, who caused a hypnotized woman to fire a pistol at a gentleman and kill him as she supposed. She acknowledged the murder, said she did it spontaneously because she did not like the man, and denied that anyone had suggested it to her.

Among Dr. J. M. Charcot's experiments was one in which the subject was presented with a blank sheet of paper which she was assured was a portrait of the doctor. The positions of the features on the paper were pointed out to her, and she soon came to see it was an excellent likeness. This sheet was then marked inconspicuously so the doctor could identify it, and it was mixed with a score of others. The pack was then handed to the subject to be looked over, and when she came to this sheet she exclaimed: "Look, your portrait!" Then after she is told that she will continue to see the portrait on that leaf after she awakes, she is aroused, and sure enough, upon looking through the pack she finds the right sheet and shows it with the same exclamation as before. The hallucination of seeing the portrait is in keeping with other easily explainable examples of like nature; but the coupling it with a particular sheet and identifying it among twenty *just alike*, looks mysterious. But the fact is, no two sheets *are* exactly alike. Each one has its individual specs, scratches, creases, and various sorts of marks, which are visible to any one who pays attention, and it has its peculiar smell and feel to anyone of sufficient sensibility to perceive them. When the doctor associated the hallucination with a particular sheet, the exalted sense of the subject would enable her to observe the distinguishing marks it might possess, and thus to pick it out. If the sheet is turned wrong side up, she detects it, and says the portrait is on the other side. An extraordinary exaltation of sense would be required for that, yet there have been examples of such exaltation that would seem to be equal to this.

The hallucination in such a case as this, was made by Dr. Charcot to last several days.

There are certain postures and gestures which are said to be the natural expressions of certain mental and emotional states. This means that the relationships between the muscles and the brain cells are such that when certain of the latter are in a particular state of excitement an overflow of stimulation to the muscles causes them to assume a particular attitude. The converse of this is also true, namely, that if the attitude be assumed by or imposed upon the muscles, there will be a tendency to cause in the corresponding brain cells, an activity which constitutes the corresponding mental or emotional state; that is, the machine is worked backwards.

Thus, if you cause a man to adopt a haughty bearing and lofty attitude, and dress him up in smart style to correspond, he will at the same time become possessed with a feeling of arrogance or pride. In the ordinary conscious states such induced feeling is more or less counteracted, diluted or neutralized by the thousand and one other stimulations by which we are assailed from the environment, but when a person is in the hypnotic state and the influence of these distracting stimulations is cut off, this phenomenon can be observed in its full effect. There are generally several sorts of muscular expression to accompany each general emotional state, and to arouse the general emotional state in a hypnotic subject, it may be necessary merely to place him in one of these attitudes of expression in order to induce the emotion in his brain and through it the other expressions of that emotion.

Thus if the hand of the hypnotic subject be placed upon the top of his head often he will draw himself up to his full hight, throw back his head and assume a look of lofty pride. But if the first position is not sufficient to cause the rest, the operator has only to throw back the subject's head and straighten up his legs and backbone, when the required emotional state will be induced and exhibited in the facial expression. Experiments proving these facts, were first made by Mr. Braid, and afterwards repeated and extended by many others. To make your hypnotic subject fight, double up his fist and raise his arm. To make him devout, put him on his knees and clasp his hands together. "Raise his head while in prayer, and his lips pour forth exulting glorifications as he sees heaven opened and the majesty of God raising him to his place; then in a moment depress the head, and he is dust and ashes, an unworthy sinner with the pit of hell yawning at his feet. Or, compress the forehead so as to wrinkle it vertically, and thorny toothed clouds contract in from the very horizon, and what is remarkable, the smallest pinch and wrinkle, such as will lie between your nipping nails, is a sufficient nucleus to crystalize the man into that shape, and to make him

all foreboding; as again the smallest *expansion* (of the skin) in a moment brings the opposite state with a full breathing of delight. Raise the head next and ask, (if it be a young lady) whether she or some other is the prettier, and observe the inexpressible hauteur and the puff sneers let off from the lips which indicate a conclusion too certain to need utterance. Depress the head and repeat the question, and mark the self-abasement with which she now says 'she is,' as hardly worthy to make the comparison. In this state whatever posture of any passion is induced, the passion comes into it at once and dramatizes the body accordingly."

Many various sorts of ideas can be induced by appropriate posturing of the subject. If the hand be raised above the head with the fingers bent upon the palm, the idea of climbing, swinging, or pulling upon a rope is excited. If the arm hangs down and the fingers are then bent upon the palm, the idea of lifting may be suggested.

In making suggestions to the subject verbally, much effect may be obtained by the particular tone and stress which the operator puts into his words. Thus if he says, "there is an animal, what is it?" the subject will answer, cow or sheep, etc., or wolf or bear, etc., according as the tone of the questioner indicates indifference or seriousness.

It is evident that in all these performances an extraordinary amount of force is concentrated upon certain tracts of cerebral cells, leaving the rest unstimulated and inactive. It is equally evident that the senses are the avenues through which this force acts upon the cerebral cells. In some of the cases last cited, the avenue was the muscular sense, in others the auditory, &c. No new principles of action are involved over those which govern the waking state. We are never so wide awake, but that some of our cerebral tracts are dull and inactive, and probably never so sound asleep, but that some tract is active or liable to be made so by an incoming stimulus. The principles above will still remain in force after we admit the existence of the psychical or mind-reading sense, for such sense is still an avenue of physical energy like the rest. The concentration of intensity, which in hypnotism is imparted to the cerebral cells, is forwarded from these in motor activities of like proportional force and vigor; so that the physical ability in any direction is greatly increased for the time being. That it is the concentration of force upon a narrow line of action to which this extraordinary power is due, is further shown by the fact that it is developed in cases of great excitement in the ordinary waking state. I once knew a boy at school who was "kept in" by the teacher and ordered to study his lessons. As soon as the teacher left, the boy started to make his escape and was discovered by the teacher, who instantly returned in pursuit, and the boy, stimulated by the excitement, leaped a high tight board fence

which the teacher could not do, nor he either in an ordinary state of mind. It is related of a Kentucky pioneer, that when pursued by Indians upon one occasion, he suddenly found himself confronted by an immense tree which had fallen directly across the path on which he was fleeing, and the limbs of which made a barrier many feet high. His pursuers thinking they now had him, gave an exultant yell and dashed forward. Under the stimulus of this, he made a mighty effort and by a miraculous leap cleared the barrier and by the time thus gained, while the Indians were recovering from their astonishment and finding their way around the obstacle, he made good his escape. Other cases involving the same principle have been cited above.

Carpenter well enough remarks that mental actions in the states of natural and artificial reverie and abstraction, and the bodily movements which are the expressions of those states, "are to be regarded as essentially *automatic* in their nature, the course of thought being entirely determined by the play of suggestions upon the associations previously formed." But as observed above, ordinary life differs from these states, only, in showing a less degree of abstraction. There is absolutely no definite boundary line possible. And certainly there is no condition of finite existence actual or conceivable, in which the course of thought is not entirely determined by the play of suggestions upon the associations previously formed. If our actions are automatic in one state they are in all the others. Since the condition of the brain in the various emotional states exerts so much influence upon the glandular secretions and the blood, it is apparent that in the hypnotic and biological states in which the emotions can be made more intense than they ordinarily are in the waking state, the effects on the secretions could be made proportionally intense. And whatever beneficial effect upon the secretions there is to be had through the mental states, it is intensified when the patient is in the hypnotic condition. Thus it is told, that "a lady who was leaving off nursing from defect of milk, the baby being thirteen months old, was hypnotized by Mr. Braid, and whilst she was in this state he made a few passes over the right breast to call attention to it. In a few moments her gestures showed that the babe was sucking (in her imagination) and in two minutes the breast was distended with milk at which, when subsequently awakened she expressed the greatest surprise. The flow of milk from that side continued most abundant; and in order to restore symmetry to her figure, Mr. Braid subsequently produced the same change on the other; after which she had a copious supply of milk for nine months." Again, a female relative of Mr. Braid was the subject of a severe rheumatic fever, during the course of which the left eye became seriously implicated, so that after the inflammatory action had passed away there was an

opacity over more than one half of the cornea which not only prevented distinct vision but occasioned an annoying disfigurement. Having placed herself under Mr. Braid's hypnotic treatment for the relief of violent pain in her arm and shoulder, she found to the surprise alike of herself and Mr. B. that her sight began to improve very perceptibly. The operation was therefore continued daily; and in a very short time the cornea became so transparent that close inspection was required to discover any remains of the opacity." *Unconscious* attention in this case.

In rare cases the pulse rate has been increased or reduced by suggestion. In one case it was reduced from a regular beat of 98 to 92, and after it returned of itself to 98 it was raised by suggestion to 119 per minute. Once, bleeding at the nose was induced; and once a blister was raised under the influence of suggestion, by putting eight postage stamps on the shoulder and allowing them to remain while the sleep continued, a period of 20 hours.

As stated above, the earlier experimenters in hypnotism came to the conclusion that there was no magnetism connected with it, and that the operator could produce no effect by his silent will. This is true in the great majority of cases. The subject is governed by his own internal sense organs; but these are influenced by the suggestions of the operator audibly communicated like any other auditory stimulation. But as shown in chapter 79, there is good reason to believe that there are certain people who are sensitive to direct impressions upon their own brains made by the cerebral activities of others. Their sensitiveness in this respect is greatly intensified if they are hypnotized, just as it is in relation to the ordinary senses. The suggestions which may enter by this aveuue become assimilated in the internal sense organs just like other stimulations, and may become dominant ideas, just as if they had entered by the auditory sense.

Profound natural Sleep is a state of unconsciousness so far as ordinary external stimuli are concerned, but an extraordinary impression upon a sensory organ may force *attention* to itself and thus interrupt sleep. Profound sleep is a state of total *inattention.* In all sleep which is not profound there is some degree of attention—some idea, the organ of which is in a state of wakefulness more or less complete. A person who is accustomed to watch by a sick bed, may go to sleep as to every idea not relating to the patient; but if the patient stir uneasily or even whisper his name, he is instantly awake. So a person who desires to awake at a particular hour may acquire a habit of partial wakefulness as to that idea.

The physiological cause of sleep is the reduction of the flow of blood to the brain cells. When it is reduced below a certain point, functional activity of the brain cells is reduced below the point at which conscious-

ness is aroused. Whenever there is consciousness, it implies work on the part of the brain as to the subjects to which the consciousness relates. For we are not conscious of many things at a time. There may also be a certain degree of brain activity without arousing consciousness. Brain work, including consciousness, is, like muscle work, done at the expense of its own tissue, which is in part disrupted and wasted in the operation. (See page 497.) When this waste has gone on to a certain extent, the functional activity of the cells wasted necessarily decreases, attention ends, and the blood supply to them is automatically diminished. Repair begins as soon as waste begins, and it continues after work and waste have ceased. This is a process the reverse of waste. From the same blood from which the elements of motion were derived, the cells, by the chemical affinity of their now to some extent *nascent elements*, take up the equivalents of the chemical molecules they have lost. Consciousness is a form of work; consequently, when it disappears it is an indication that work has ceased to a certain extent, if not entirely. We know that a certain amount of brain work may go on in unconsciousness, but ordinarily the most of the brain work ceases with the disappearance of consciousness, because the supply of blood necessary for its production has by that time become too limited.

The attention ends when, by reason of the exhaustion of the brain cells, the incoming ordinary stimulus is unable any longer to produce their erection. They are, however, in the general conditions of healthful sleep, subject to erection by an extraordinary stimulation. But the exhaustion may become too great for any but the most violent stimuli. People upon whom torture is being inflicted, will often sleep in the intervals of its torments. This is told of Indians at the stake, and of Christian martyrs on the rack. It is also true of soldiers in the din of battle. There are different sorts of predisposing causes to sleep, all of which depend, however, upon the same principle of withdrawing the blood supply from the brain cells. If the stomach be overloaded, the muscular and chemical work put upon it is excessive, and an increased supply of blood is directed to it, and to the related organs concerned in digestion. This withdraws it from the brain and induces drowsiness or sleep. Fatiguing work by the muscles operates in a similar way. The hum of a mill, the gentle, monotonous beating of waves upon a beach, the droning of a dull reader, or the perusal of a dull book, produce the same result. In this sort of cases the monotonous succession of impressions made upon the sensory ganglia, does not lead to the stimulation of cerebral cells in the formation of ideas, because the attention is held to the sensory impression by the continued repetition of the sensory stimulus upon the cells of the sensory ganglia. So the accession of blood to the idea-forming cells is diminished, and they may all sink to

sleep, leaving those awake upon which the stimulus is active. But after awhile these may become exhausted and fall asleep, too. Often they remain, however, in a state of partial wakefulness, because when a person is asleep under a droning hum or monotone, he will be likely to awake upon its sudden cessation.

It is in accordance with this same principle, that when a person has a sense of fatigue from thinking steadily upon one subject, he is rested by changing his thoughts to another. In the absence of a monotonous sensory stimulus, a monotonous cerebral stimulus may often be substituted to induce sleep; for example, the persistent repetition of a formula of words which does not call up active ideas, as the conjugation of a verb, the recitation of very familiar verses, &c.

Sounds and disturbances to which a person is habituated do not interrupt sleep like those which are new, unless such disturbance is associated with a desire to be aroused.

A person sleeping for the first time in a new place is apt to be aroused by noises which do not disturb him after he is used to them. They are stimuli not attended to, which provoke counteracting stimuli as shown at the beginning of this chapter.

The reduction during sleep of the amount of blood going to the brain was shown by the experiments of Mr. A. Durham, on dogs. When he removed (under chloroform) "a portion of the skull of a dog so as to expose the cortical layer of the cerebrum, it was observed that as the effects of the chloroform passed off, and the animal sank into a natural sleep, the surface of the brain which had previously been turgid with blood and inclined to rise into the opening through the bone, became pale, and sank below its level. On the animal being roused, after a time, a blush seemed to start over the surface of the brain which again rose into the opening through the bone. And as the animal was more and more excited, the brain substance became more and more turgid with blood; numerous vessels which were invisible during the sleep being now conspicuous, and those before visible being greatly distended. After a short time the animal was fed, and when it again sank into repose those vessels contracted again and the surface of the brain became pale, as before." The retina has been examined during profound sleep and found to be paler and its arteries more contracted than while the subject was awake.

Sleep is only one of several phenomena which depend upon a diminution of the supply of blood to the brain. A blow upon the head may, in prize-ring parlance, put a man "to sleep;" a fracture in which the bone presses upon the brain preventing circulation, produces insensibility.

In *Hysteric Coma*, suspension of sensibility occurs suddenly, upon

the reduction of the blood-supply by contraction of the arteries by sudden stimulation from the vaso-motor nerves. In *Asphyxia*, as by inhalation of carbonic acid gas, &c., by strangulation, and by drowning, insensibility, as well as the reduction of the other functions, is occasioned by the stoppage of the supply of arterial blood, which supply depends upon the contact of air with the venous blood in the lungs, but which contact is prevented in the various modes of asphyxia.

So the absence of a blood-supply at once produces unconsciousness; but if the supply is partial, consciousness may be partial. And there is reason to believe that in cases where there is a readiness and alertness with respect to some special sort of stimulation, while the brain is deaf to all other sorts, the flow of blood to the alert parts continues without cessation, and those parts therefore are not asleep.

Insomnia, or sleeplessness, is a condition in which the process of the repair of brain tissue is interrupted. Consequently it is abnormal, and indicative of destruction and disease. It is one of the characteristics of acute mania, and often accompanies monomania. Loss of sleep, with its corresponding opportunity for brain repair, is, of itself, enough to cause brain disease.

Dreaming takes place when a part only of the brain cells have become awake, and while the sensory ganglia are still asleep, or chiefly so, to *external* impressions. We can not, however, be quite asleep to *internal* impressions, or else we never would be conscious of any of our dreams. The absence of congruity and continuity is due to the absence of a governing stimulus from without, and also to the partial sleep of the cerebral cells. It is evident that the whole cerebrum may be awake, together with such of the cells of the sensory ganglia as are related to the internal senses, while the part of the sensory ganglia related to the external senses are asleep, and to some extent the converse may be true. In the former case a species of cerebration may go on, which is quite connected and rational. There are numerous cases on record of mental tasks commenced and labored upon or suggested during waking hours and finished up as dreams. (See also chap. 75.)

It often happens that a stimulus may arouse the sensory cells relating to the external senses, while the cerebral cells and the perceptions remain asleep. The actions which take place in response to such stimulation are no more than reflex. Many dreams take place during the very short time often occupied in the transition from sound sleep to complete wakefulness. There are many examples to show that such processes may be practically instantaneous. A dream, the scene of which covers many distant places and extends through years of time, has been known to transpire after a sound which caused the sleeper to awake.

Sensory impressions may partly arouse a sleeping person and may sug-

gest trains of thought for the dream, and they may do this without arousing consciousness as to the sensations themselves. Thus the dreams of a person may be suggested by remarks by a bystander, which the dreamer will not remember. A dreamy, semi-delirious state may be artificially induced by the use of certain narcotics, such as the preparation of cannabis indica called hachisch. Under the influence of this drug the emotions are largely under the control of external impressions. These are greatly distorted and exaggerated and lead to false perceptions and the most extravagant ideas. These ideas are pleasurable, provided the sensory impressions which originate or color them are of an agreeable nature. Hence, those who indulge the use of the drug, take care beforehand that they be surrounded by agreeable things.

CHAPTER LXXIV.

SUBJECTIVE SENSATIONS AND ILLUSIONS.

Subjective sensations are those which are excited in the brain by alterations not caused by external stimuli, but by some internal stimulus upon the nerves of sense, or a disease or lesion of the brain. Thus, persons may have for years a constant ringing sound in the ears, due perhaps, to inadequate insulation of the auditory nerve from the beating blood vessels. Congestion of the nerves of common sensation produces "feelings of pain or uneasiness, a blow upon the optic nerve causes a sensation of light." In general, when nerves are stimulated by abnormal causes within the body, the effects are, to produce the same or similar sensations to those normally produced by the ordinary external stimulus. Subjective sensations may originate in peculiar conditions of the brain itself, or of the organs of sense, or of the nerve trunks. They may properly be called subjective if their causes cannot be traced directly to the environment, but depend on changes in the body itself.

There are often sensations in one place which are excited by causes in operation in a very different part of the body. "Disease of the hip joint is often indicated by pain in the knee, irritation of the ovary will cause pain under the mamma, various disorders of the liver occasion pain under the left scapula;" "the sudden introduction of ice into the stomach will cause intense pain in the supra-orbital region, and the same pain is frequently occasioned by the presence of acid in the stomach and may be very quickly relieved by its neutralization with an alkali." In many cases there is no *direct* nervous connection between the disordered locality and the place where the symptoms are felt. The connection is indirect through a common center, and in this center it must be that an afferent stimulation from a part really affected, transfers itself to adjacent cells, connected with parts not affected; the sensation to them being the same as if it came from the part with which they are

connected. The parts to which these subjective sensations of pain refer, sometimes do become actually diseased after awhile, on account of the habitually directed consciousness and attention to this part. (Carpenter.) It has been remarked elsewhere that the sensation produced at the central ganglion by an afferent nerve, is as if it were located at the sense organ, and if the nerve be cut and the sense organ separated from it, the sensation is still referred to the same place. "Thus, after amputations, the patients are for some time affected with sensations (probably excited by irritation at the cut ends of the nerves) which they refer to the removed extremities; the same has been noticed in regard to the eye as well when it has been completely extirpated, as when its powers have been destroyed by disease.

There is a close relationship between *Subjective Sensations* and *Illusions*. The former may arise from disordered activities of various parts, muscles, viscera, &c., while the brain and nervous system are responsible for the latter. An illusion is the sensation of a memory revived in such a way that it appears to be real and original instead of a memory. In our ordinary condition, our consciousness is not usually so concentrated upon any mental process but that there is a sub-consciousness of our external surroundings, and of the fact that the things we are thinking of, are things of the memory and results of past impressions. As a general rule, to which there are explainable exceptions, in cases of illusion this ordinary sub-conscious sense of our surroundings is in abeyance. We are "lost in thought" and forget where we are. The things we have in contemplation seem exceedingly real. Our attention is narrowed down upon certain memory organs, and their activities remain unconditioned and unrestrained, and the ideas remain uncontradicted by stimulations from the present environment. As to those things, for the time, we live wholly "within ourselves." We are in a condition of abstraction, or partial hypnotism, and the memory does not seem a memory, but the original activity itself, which preceded the memory and laid the foundation for it. So, if under these conditions, the thought wanders back to a sensory impression, one of sight for example, the sensation we get is not one of a *memory* of something seen, but is a sensation of actually *seeing* it now. In the ordinary state, a person can "picture in his imagination" just how his absent friend looked the last time he saw him; but the other memories which crowd around, and the new sensory impressions which constantly assail him, correct the tendency which this picture has to seem to be an original impression and to show the friend actually present. When the person is in a condition to be deceived by an illusion, these restraints are removed, and the sensory impression is revived as if it were original instead of a memory, and he sees the image of his friend projected in

front of him as really as if the friend were there. Evidently in such case the machinery is worked backwards. We saw in the last chapter, examples of this backward motion in hypnotic subjects, where they are caused to take on particular mental or emotional states, by being made to assume the postures and muscular movements which those emotional states ordinarily lead to, and which are expressive of them. So, too, it is worked backward when the operator says to the subject in a serious and alarmed tone, "See that bear!" The sensation experienced by the subject is the same as if the bear were actually in front of him, and it is a true case of illusion. It is presupposed that the subject has seen a bear in reality and therefore has the organs made by bear stimulations coming through the eye up the optic nerve. These organs are restimulated by what the operator says, the stimulation passing from the auditory sense indirectly to the sight memory organs. Thus, these which are the last in the sight series are the first to be affected by this stimulation. If it goes further, it must be towards the optic nerve, and the retina of the eye, that is, backwards. An illusion of seeing might be created in the brain when the eyes are closed. But there is reason to believe, as we shall see, that the illusion may traverse backwards down the optic nerve and retina, and be projected into the space beyond.

Those illusions of the cerebral organs which cannot be represented as simple sensory pictures, are called *delusions.* The greater part of our ideas and opinions, when acting absolutely alone and not co-ordinated or limited by others, become delusions; which is due to the fact that there are no independent and unrelated objects in the universe from which we get our stimulations.

Sir Isaac Newton, from long and earnest attention to the study of light and the spectrum of sunlight, produced such an effect on his brain that for several months the spectrum appeared to him whenever he began to think about it, even in the dark.

From the subjective nature of an illusion, the same spectre is never seen by more than one person, except in those cases in which there is a real object associated with the spectral illusion and forming a basis or nucleus for it; as, for example, the case of the ghost of the sea cook, seen by a whole ship's company, in chapter 72.

Violent stimulations are apt to erect in our internal senses, organs of extreme sensibility which are liable to undue and abnormal excitement upon being restimulated, and which easily become stimulated, especially when, through disease or general weakness, the rest of the organs are not strong enough to counteract and contradict it. A lady, "having been frightened in childhood by a black cat which sprang out from beneath her pillow, just as she was laying her head upon it, was ac-

customed for many years afterwards, whenever she was at all indisposed, to see a black cat on the ground before her, and although perfectly aware of the spectral character of the appearance, yet she could never avoid lifting her foot as if to step over the cat when it seemed to be lying in her path." (Carpenter.)

"The Rev. P. H. Newnham tells us of three occasions during the autumn of 1883, on which he saw and recognized in church the figures of persons who proved not to have been there. In two of the three cases the figure thus seen had peculiarities which made it quite unmistakable, and was observed in the same place more than once during the service, just as any real member of the congregation might have been. The third case is this: 'I went as usual to the school about a quarter of an hour before service, and either spoke or nodded to all the teachers present. I particularly noticed one in whom I am much interested, sitting with her class, nodded to her, and she smiled back again. Subsequently, in church I noticed her again, and counted her (I always count my congregations) *twice over*, once when I counted the entire number present, once when I counted children and adults separately. It turned out, however, that the girl had not been present. I think I was never so surprised in my life. I made several inquiries, but there was no mistake. She had been detained at home, much to her vexation and annoyance, during the whole afternoon in which I had seen her in two different places, and had had my eye on her practically the whole time.'"[1]

The Rev. Prof. Turner, of Manchester, relates that he saw, one night, suspended from the ceiling of the room, "a large chandelier with some ten scroll-shaped branches, and the jets shining brightly through the ground-glass globes at the end of each. I at once recognized the chandelier as a duplicate of the chandelier which hung in the college chapel connected with the Countess of Huntingdon's college at Cheshunt, where I received my training for the ministry. I moved my head to see whether the phantom moved too. But no, it remained fixed, and the objects behind and beyond it became more or less completely visible as I moved, exactly as would have been the case had it been a real chandelier." He woke his wife to look, but she saw nothing of course.

An English officer in India relates the following: "I had been taking luncheon with some friends, and after it was over, my host proposed that I and my fellow guest should accompany him to see some alterations he was making in his grounds. After we had been out some little time looking at these changes, a native servant approached me with a message from my hostess, asking me to go into the house to speak to her. I at once left my friends and accompanied the man back to the house, following him through the veranda into the room where the

[1] Phantasms of the Living, Vol. 1, page 475.

luncheon had been laid. There he left me, and I waited for my hostess to come, but no one appeared, so, after a few minutes, I called her by name, thinking she might not be aware that I had come in. Receiving no answer after once again repeating her name, I walked back into the veranda, where on entering I had observed a durzee (or tailor) at work, and asked him where the man was who came in with me. The durzee replied, 'Your Excellency, no one came with you.' 'But,' I said, 'the man lifted the chik (the outside veranda blind) for me.' 'No, your Excellency, you lifted it yourself,' the durzee answered. Much puzzled I returned to my friends in the grounds, exclaiming, 'Here's a good joke!' and then telling them what had happened, and what the durzee had said, I asked them if they had not seen the servant who called for me shortly before. They both said they had seen no one. 'Why, you don't mean to say I have not been in the house?' I said. 'Oh yes, you were in the midst of saying something about the alterations when you suddenly stopped and walked back to the house; we could not tell why,' they both said. I was in perfect health at the time of the occurrence, and continued to be so after it." (Phantasms, 499, Vol. 1.)

Dr. Charles M. Smith, of Franklin, St. Mary's Parish, Louisana, relates that a lady of his acquaintance, Mrs. P., lost her life at Last Island in the terrible hurricane of August 1856. "Nearly two months afterwards, on my way to visit a patient in the country, I met Mr. Weeks, a brother of Mrs. P., and in the buggy with him, a lady so wonderfully like Mrs. P., that, but for my knowledge of her death, I would have declared it to be herself. The carriage and horses used by Mr. Weeks were easily distinguished by certain well-marked peculiarities from any others in the parish, and I saw these as distinctly as the occupants themselves." Dr. Smith bowed, and called Mr. Weeks by name, but no notice was taken, and the buggy passed on.

Returning home an hour later, he made particular inquiry, and found that no persons in the least resembling those he had seen had arrived in the village, and he afterwards learned that Mr. Weeks had been at his home, 30 miles away, at the time. "The conclusion seemed inevitable," he adds, "that the whole affair was an optical delusion." (Phantasms.)

Illusions of hearing are not so common as those of sight, but they sometimes occur. "A gentleman, recently recovered from an affection of the head, in which he had been much reduced by bleeding, had occasion to go into a large town a few miles from his residence. His attention was there attracted by the bugle of a regiment of horse sounding a particular measure which is used at changing guard in the evening. He assured me that this sound was from that time never out of his ears for about nine months. During all this period he continued in a very pre-

carious state of health; and it was only as his health became more confirmed, that the sound of the bugle gradually left him." (Abercrombie.)

Dr. Sam Johnson relates that he once heard the voice of his absent mother distinctly call his name, "Sam!" "A lady, whom I attended some years ago, in a slight, feverish disorder, saw distinctly a party of ladies and gentlemen sitting round her bedchamber, and a servant handing something to them on a tray. The scene continued in a greater or less degree for several days, and was varied by spectacles of castles and churches of a very brilliant appearance, as if they had been built of finely cut crystal. The whole was in this case entirely a visual phantasm, for there was no hallucination of mind. On the contrary, the patient had, from the first, a full impression that it was a morbid affection of vision connected with the fever, and amused herself and her attendants by watching and describing the changes in the scenery.

"A gentleman, who was also a patient of mine, of an irritable habit, and liable to a variety of uneasy sensations in his head, was sitting alone in his dining-room in the twilight, the door of the room being a little open. He saw distinctly a female figure enter, wrapped in a mantle, and the face concealed by a large, black bonnet. She seemed to advance a few steps towards him and then stop. He had a full conviction that the figure was an illusion of vision, and amused himself for some time by watching; at the same time, observing that he could see through the figure so as to perceive the lock of the door, and other objects behind it. At length, when he moved his body a little forward, it disappeared." (Abercrombie.)

Although there was no "hallucination of mind" in these two cases, nevertheless, it is probable the trouble was in some part of the cerebral memory tract. A sort of delirium affected certain organs by which the images were revived, while the rest of the organs, not being unduly erethised, received true representations from the environment, and gave true perceptions which contradicted and corrected the false ones given by the other internal sense organs.

When we dream, a portion of the organs are thus excited, and give sensations of more or less connected memories, and they seem to us real, because the rest of the organs, including the external senses, are dormant and do not furnish any corrective or contradictory perceptions. In these two cases, the internal senses furnished the data for the spectral illusions, while the external senses furnished true reports of what there was in sight, which contradicted and corrected the others; and that is why there was no "hallucination of the mind." And yet, whatever hallucination there was, was of some of the internal senses, and not of the organs of sensation.

"The wicked flee when no man pursueth," because their "imagina-

tions are haunted." There are cases on record of murderers being haunted by the apparitions of their victims and driven to give themselves up to justice.

"A gentleman mentioned by Dr. Conolly, when in great danger of being wrecked in a boat on the Eddystone rocks, said he actually saw his family at the moment. In similar circumstances of extreme and immediate danger, others have described the history of their past lives, being represented to them in such a vivid manner, that at a single glance the whole was before them, without the power of banishing the impression." This is often related of persons who have been rescued from drowning. The extreme erethism of the cerebral tissues extends to all the memory organs, and everyone is so intensely aroused that it would, if considered by itself, afford the elements of a vision. Persons under the stimulating effect of opium, are apt to experience the same sort of stimulation of organs that produces visions. Dr. Gregory, upon returning by sea from a visit he had made to a lady, a relative of his, in whom he was deeply interested, and who was far advanced in consumption, took a small dose of laudanum to prevent sea-sickness. As he lay upon a couch in the cabin, the figure of the lady appeared to him, as vivid and as natural as if she had been actually present. "He was quite awake, and fully sensible that it was a phantasm produced by the opiate along with his intense mental feeling, but he was unable, by any effort, to banish the vision." Another case of Dr. Abercrombie's was one in which the patient was afflicted by a painful disease, to deaden the pain of which, the doctor gave him opiates. Under the influence of these he had very remarkable visions, the subject of which was a matter which had been the talk of Edinburgh for some time. "The characters succeeded each other with all the regularity and vividness of a theatrical exhibition; he heard their conversation, and long speeches that were occasionally made, some of which were in rhyme; and he distinctly remembered and repeated next day, long passages from these poetical effusions. He was quite awake, and quite sensible that the whole was a phantasm, and he remarked that when he opened his eyes the vision vanished, but instantly reappeared whenever he closed them." A great many cases of visions have occurred to persons known to be affected by epileptic or other nervous affections, and to persons just "coming down" with sickness of some kind, when, as may be supposed, the nervous system is first abnormally affected and carries to the brain an unusual and unbalanced stimulation. "Dr. Gregory used to mention in his lectures a gentleman liable to epileptic fits, in whom the paroxysm was generally preceded by the appearance of an old woman in a red cloak, who seemed to come up to him and strike him on the head with her crutch; at that instant he fell down in a fit." Another

case is reported of a man in Berlin, who, by strong emotional stimulation, had been thrown into an excited cerebral state and was, during several months, while awake, haunted by apparitions of men and women, animals and birds. Another case was that of a saloonkeeper, who saw a soldier trying to force himself into the house in a threatening manner, and upon rushing forward to resist him, found it was a phantom. This vision was supposed to have had its origin in a quarrel which he had some time before with a drunken soldier. After this he had numerous visions of people dead and living, which ceased after medical treatment. An American in Great Britain "was seized with a severe headache, and at the same time had distinct visions of his wife and family whom he had left in America." Such phantoms are common in febrile diseases, or upon their approach. In one such case, a lady saw a phantom man enter her room, pass the foot of her bed, and disappear in a closet on the opposite side.

A lady "during a severe illness repeatedly saw her father, who resided at the distance of many hundred miles, come to her bedside and withdrawing the curtain address her in his usual voice and manner."

A farmer returning from market one night, at a time when typhus fever was prevailing in the neighborhood, and he himself had been suffering with headache and languor, saw a bright and peculiar appearance in the road which his imagination pictured as the Saviour. He was greatly alarmed, galloped home, was soon down with the typhus fever, and died in ten days.

In another case, a lady returning from a party went into a dark room and there saw a figure of death as a skeleton with an uplifted dart. With this he seemed to strike her in the left side. She directly had a severe fit of fever with inflammation in the left side, from which, however, she recovered.

A gentleman in a mild fever, was, during several weeks, visited by the apparition of an old gray-headed man of benignant aspect, who always entered the room by a door on the left-hand side of the bed, passed the end of the bed, and seated himself on a chair on the right-hand side. The visits were in general daily, a day being missed occasionally, however. The same gentleman at another time while in health, saw a female figure kneeling in the corner of the room for several seconds.

Dr. Abercrombie also reports the case of "a clergyman who, aged 56 and accustomed to full living, was suddenly seized with vomiting, vertigo and ringing in his ears, and continued in rather an alarming condition for several days. During this time he had the sound in his ears of tunes most distinctly played and in accurate succession. This patient had at the same time a very remarkable condition of vision, such as I have not heard of in any other case. All objects appeared to him inverted.

This peculiarity continued three days and then ceased gradually, the objects by degrees changing their position, first to the horizontal and then to the erect."

Sir David Brewster, in "Natural Magic," gives an account of Mrs. A., an intelligent lady of vivid imigination, who was the subject of a number of remarkable illusions. Some of these occurred when she appeared to be in ordinary health, but the most notable happened when her health was weak from bronchitis and bad digestion. The first occurred about the year 1820, when undressing after a ball, she heard herself called by name repeatedly and unaccountably. Ten years after, she heard what she was sure was her husband's voice calling her loudly, distinctly and repeatedly to come to him. She opened various doors to find where he was, but without success, as he was not near the house at the the time, and had not called her. Shortly after this she saw the figure of her husband, which stood by the fire, gazing at her, and afterwards moved off to the window where it disappeared, after remaining visible four or five minutes. The figure appeared so solid and real as to conceal the objects behind it. A short time after this, January, 1830, she saw the apparition of a cat, and she was so sure it was real, that when requested by her husband, who was present and who knew it to be an illusion, to touch it, she pursued it about the room till it disappeared under a chair. She was convinced as to its true nature when the real cat was brought from another room. A month after this she saw the apparition of a friend who was in Scotland and in perfect health. She saw the image in a glass as if the figure were looking over her left shoulder, her eyes meeting those of the image. She gazed at it some minutes and noticed its drapery, which was a shroud. On turning to look for the figure behind her, she saw nothing, and it had also disappeared from the glass when she turned to that again. Twice after this she saw apparitions of deceased friends; once the sister of her husband whom she saw seated in a large easy chair holding a handkerchief in one hand; it remained about three minutes. At another time she saw the figure of a deceased friend move across the room and take a seat by the fire-place. Knowing its illusory character, Mrs. A. crossed the fire-place and sat down in the chair occupied by the figure, which then vanished. For some hours preceding some of these visions, she had a peculiar sensation in the eyes, which went off when the apparition disappeared.

In 1857, Mr. Adrian Stokes, of Liverpool, was one night awakened by his wife calling out, "Oh! Adrian, there's Agnes!" Agnes was her only sister, and she thought she saw her sitting on an ottoman at the foot of the bed. She felt frightened at first, but recovering herself she reflected that if the figure were real it would be reflected in a mirror which was in view from the bed. Turning her eyes toward it, sure

enough by the light of the fire in the grate "she saw the full reflection of the form seated on the ottoman looking at a bunch of keys which she appeared to hold in her hand." While endeavoring to call her husband's attention to this phenomenon, it vanished. (Phantasms of the Living.)

The following story was told by Dr. Andrew Combe: "A gentleman, a friend of his, has in his house a number of phrenological casts, among which is particularly conspicuous, a bust of Curran. A servant girl belonging to the family, after undergoing great fatigue, awoke early one morning and beheld at the foot of her bed the apparition of Curran. He had the same pale and cadaverous aspect as in the bust, but he was now dressed in a sailor's jacket, and his face was decorated with an immense pair of whiskers. In a state of extreme terror she awoke her fellow servant, and asked whether she did not see the spectre. She, however, saw nothing, and endeavored to rally her out of her alarm, but the other persisted in the reality of the apparition, which continued visible for several minutes. The gentleman, it appears, keeps a pleasure yacht, the seamen belonging to which are frequently in the house. This, perhaps, was the origin of the sailor's dress in which the spectre appeared; and the immense whiskers had also been borrowed from one of these occasional visitors." (Abercrombie.)

This story illustrates well how dreams are composed by the putting together of fragments of various memories. It also shows the practical identity in origin of ordinary dreams and of waking visions. In both cases they may seem to the subject to be real, and in either case they may be contradicted by the activity of either the external or internal sense organs, so that the subject knows he is being entertained by a fiction, though this oftener happens in the day visions than in the dreams. When a person is awake he can test his vision by the external senses, or by his judgment, or standard cerebral organs.

A person afflicted with delirium tremens sees all sorts of repulsive creatures, such as toads, snakes, and slimy, creeping animals, or dancing demons, or fairies; but unless he is pretty far gone, his judgment informs him what is the matter, and he is aware of the illusion, notwithstanding the realistic appearance of the vision.

It very often happens that the abnormal condition of the cerebral tissues is not sufficient without an external guiding sensation to frame an illusory, subjective sensation. But by having a real object for a basis, the sensation of it may be so perverted as to construct it in a very illusive form. In such cases the excitement of the organs involved may be but little above the normal of mere attention, provided they are not contradicted by others also active. Thus, to a timid person, an object seen indistinctly at night may give a suggestion of something mysteri-

ous or terrifying. A black stump becomes a prowling beast or a skulking assassin; a white object is a ghost, &c.

Sir Walter Scott relates a story of a gentleman, who one evening was reading an account of the life of a poet who had recently died, and with whom he had been well acquainted. His emotions were considerably aroused as a result of his reading. After a time he laid down his book and went into an adjoining hall, which was dimly lighted by the moon. There he saw right before him in a standing posture, the exact representation of his departed friend. He paused long enough to observe the details of dress, posture, &c., which corresponded with his memory of them, and then, sensible that it was all a delusion, he walked up to it. As he did so the apparition resolved itself into the various materials of which it was composed. "These were merely a screen occupied by great coats, shawls, plaids, and such other articles as usually are found in a country entrance hall."

It is evident that in complete hallucination of vision (or any other sense), the centers of sensation must be stimulated to an extent equal to that which usually arises when the stimulation comes by the ordinary route of the sense organs, and yet not coming from any object in the external environment.

If the hallucination is of a simple sensation, as of a flash of light, it might arise from a stimulation of the retina or of the optic nerve by a blow, a lesion, or other abnormal cause. But if it is a revived image of a former sensation, it must arise from the restimulation of the cerebral memory organs, the internal sense organs.

But the halluciation at times consists of images newly made, like dreams, from materials already in the memory, of course, but differently associated, so that as a whole it is quite new. Such images are formed as ideas of a complicated nature always are, by the powerful erethism of parts of various memory organs; at the same time, such action resulting in the formation of new organs whose ordinary stimulation would produce the sensation of a fancy, but whose extraordinary stimulation might produce an illusion or hallucination. The hallucinations of the insane are usually uncontradicted, and so take full sway of the patient, causing him to adapt his actions to false conceptions of the condition of his environment. The hallucinations of the sane are, sooner or later, contradicted. Often the subject has in reserve, a sufficient number of organs not involved in the production of the image in question, to set up an idea inconsistent with the realty of the first one, and so he may know at the time, that his vision is a hallucination. Or, after it has passed off, and other ideas supervene, he becomes undeceived by them as to the reality of the vision.

While the hallucination endures, it is so complete, that the excite-

ment aroused in the cerebral organs overflows backwards along the optic nerve to the retina, and from thence, to all *appearance*, it is projected into space, forming an image which appears to occupy the same position that a real object would have to occupy in order to produce the same sensation in the brain.

This position, or point of projection in space, is called by the French, the *point de repére.* The hallucination is often initiated, or modified, or influenced by some real object in the environment. Such object may then occupy the *point de repére*, and the details of the hallucinatory image be constructed about it, as in the case mentioned by Walter Scott, and quoted above. When such real object furnishes a nucleus for the hallucination, and forms a part of its structure, if the eyes are turned away from it, that much of the image is torn away, and so the image usually falls to pieces. But when the image is wholly constructed within, and projected without through the sense organ, the external projection appears to share in all respects the conditions of an incoming stimulation from a real object. Thus it was observed by M Fere, that a prism applied to one eye doubled the imaginary object. A magnifying glass, placed in the line of the projection, increased the size of the supposed object, while, if the glass were reversed, the object was diminished. Equally remarkable, when a mirror is placed so as to reflect the *point de repére* to the eye of the subject, the image of the imaginary object may appear in the glass.

In two spontaneous cases cited above, the image was said to have been seen in a mirror. It is proper to state that the experiments with prism, spy-glass, etc., have been successful in some cases only, not in all.

Those hallucinations or illusions which persist when the eyes are closed, are no doubt to be explained as the sensation of the restimulation, or the first construction, of an internal sense organ merely. But those cases in which the spectre is projected to the *point de repére*, and especially the cases in which the looking glass, spy glass and prism are found to influence the conditions of the vision, require a further explanation. The possibility of working certain sorts of machinary backwards has been pointed out. The retina and the internal sense organ stand to each other in the same relationship as two electric dynamos, connected by conducting wires. If power be applied to *either* of the dynamos, it will pass to the other and cause it to revolve. There is good reason to believe that there is the same reciprocity between the brain organ and retina, and that the application of energy to *either* will set up motion in the other. The two considered together constitute a single machine, bound into one by the connecting nerves. If we suppose the dynamos above to be driven by an overshot water-wheel, we might regard the

three as constituting a single machine, and supposing power to be applied to the end dynamo (and leaving friction, waste, &c., out of the account), we can imagine that dynamo to drive the middle one, and that to turn the water-wheel backwards and lift the water back to its position above the dam. And so I take it, we may add a third term to the machine composed of the brain organ and the retina, and that will be the medium which conveys the force to the retina from the outside when the action is in the usual direction. That medium is the *ether* whose vibration normally sets up the action in the retina, which, transferred to the brain, causes the sensation of light. Worked the contrary way, the excitement of the brain organ by causes within the brain, sets the retina into activity, which in turn communicates the motion to the ether beyond. There is nothing violent in this hypothesis. It accords with analogy that the relationship well known to exist between the energy of an excited retina, and that of the light-bearing ether, may be reciprocal. Granting that it is, and that the action of the retina originating in the brain behind it, may communicate actual motion to the ether in front of it, the experiments with the spy glass, mirror and prism become easily explainable. Otherwise it is difficult to see how the action wholly in the brain can produce there the sensation of an image which can be reflected in a mirror outside of it.

The sort of motion communicated to the ether by the eye is probably of a nature similar to that projected from the pole of a magnet, which makes an excursion as a positive current, and causes a return of a complemental negative current, or vice versa. It is these rays of force or energy thus darted forward from the eye that the prism, the spyglass and the mirror deal with, by refracting, converging or diverging (magnifying or minifying) and reflecting them. It is by the return currents to the eye of the subject that he becomes aware of the action of the instruments. The impressions he gets of the position, shape, size, &c., of his phantom may also arise in part, or whole, from sight stimulations from the neighboring objects. (See Darwin's experiment further on.) This theory supposes that these lines or rays of force can be reflected and analyzed like light. There is strong reason to think the polar energies and light are movements of the same ethereal substance. Nervous energy as it is manifested in the nerves, ganglions and brain, and projected from the body into the space around it, is beyond reasonable doubt, a motion of the same substance. The mode of the motion may not be identical with either light or magnetism, and yet possess qualities and capacities belonging to both. If the organ of the cerebral fancy can thus disturb the environment by a real physical motion like that of light or magnetism, it might reasonably be anticipated that the motion would or could be communicated to another person so that he could be

affected by the same illusion. If these lines of force could be reflected from a mirror it would seem possible they could be seen by a second person. I have not, however, met with any report of such a case. The scarcity of this sort of illusions with the necessary accompaniments of mirror, second party on hand in the proper position, &c., may account for this.

It would further seem possible to get a photograph from these lines of force. Twenty years ago there was a great interest excited by what was called spirit photography. Very much of it was palpably fraudulent. If any were genuine, the phenomena would be accounted for under this hypothesis: that the objects photographed were cerebral ideas whose organs projected their agitations into the environment, developing lines of force similar to those which would have been reflected from a solid body. For we are to remember that it is the rays of force that do the business in photography, regardless of their origin, and *if* we can prove the development of such rays by the action of the brain, the possibility of their decomposing the film on the plate, and making a picture of *something*, can be conceded without difficulty.

But if the agitations of internal sight organs are (under some conditions) competent to set up action in the environing ether, why not those also of other organs? From what was said in chapter 36 it would appear that wherever there is either polar tension or polar motion, there is a *field of force* extending in all directions, across which, or in which, the influence of induction is communicated. That the organs of the brain are polar bodies, and the nerve currents, polar currents, hardly admits of doubt. It follows that they may be surrounded by fields of force, across which they may send their inductive influence. (See figs. 143, 144.) There are many facts going to show that this is the case. The different sensations set up in us by the action of different brain organs, may be supposed to indicate differences in pitch in the movements peculiar to the organs. When these influences, projected into the environment of the brain, come into contact with the brain of another person which may be within the same field, the corresponding organs of the latter brain are affected so as to take up a motion like that of the first, so that a sensation is aroused in the second brain similar to that in the first. As it is stated rather inaccurately in common language, there has been a transference of thought. (See chapter 79.)

That illusions are due to an unequal stimulation of organs, is shown where spectral illusions arise from the fatigue of overstimulation of a *part* of the organs concerned. Darwin performed this experiment. Upon a *yellow* paper, four inches square, he wrote in *blue* capitals the word BANKS. Then, with his back to the sun, he gazed a minute exactly on the middle letter. Then closing his eyes, he could see the *word* in

yellow, on a ground of *blue*. Then, opening his eyes on a yellowish wall twenty feet off, the word was seen *magnified*, and in golden characters. The cause of the illusion, as to the colors in such cases, is explained on page 440. The magnified appearance of the word is due to another illusion. When the word was first seen, the visual angle, and the amount of the retinal surface involved, was determined by its distance away, say five feet. When the eye rested on the wall, *estimated* in a sub-conscious manner to be twenty feet distant, although the visual angle remained the same and the same patch of the retina was concerned in the vision, the letters would appear four times as big each way. The estimate of distance unconsciously goes along with every sight sensation. A man, 100 yards away, does not appear to get larger if he approaches us, although at 20 yards the visual angle is five times as great.

Abercrombie relates that a friend of his, after bending over a small print of the Virgin and Child and looking at it intensely for some time, raised his head and was startled to see the life-size figure of a female with a child in her arms at the further end of the room. The upper part of the body only was represented, and he at once perceived that the illusion was due to the impression made upon the eye and brain by the picture. The increased size was due to the projection of the image to a distance. The illusion remained distinct for about two minutes, or until the parts fatigued by the steady gaze had recovered.

Dreams almost always consist, in part at least, of illusions. Any image which may be aroused is apt to remain for a moment unbalanced and uncontradicted, so that it yields that unquestioned sensation that has the realistic properties belonging to an objective impression. Such illusions, as well as waking ones, are often shaped by objective stimulations. External stimulations of the senses during sleep often form the initiatory suggestions of dreams. The rays of the moon or sun shining upon the sleeper may suggest images of a glorious, gorgeous nature. But sounds especially are productive of suggestion. M. Alf Maury relates "that when a pair of tweezers was made to vibrate near his ear, he dreamt of bells, the tocsin, and the events of June, 1848."

"Scherner gives an amusing case of a youth who was permitted to whisper his name into the ear of his obdurate mistress, the consequence of which was that the lady contracted a habit of dreaming about him, which led to felicitous change of feeling on her part."

"The dream illusion of falling down a vast abyss, is plausibly referred by Wundt, to an involuntary extension of the foot of the sleeper."

The barking of a dog caused Sully to dream that a dog came and licked his face. (See Sully's **Illusions**.)

CHAPTER LXXV.

AUTOMATIC ACTION OF THE CEREBRUM.

A great many facts which have been presented in former chapters, compel the conclusion that the cerebrum is automatic in its actions, the same as the other ganglionic centers of the brain. The terms voluntary and automatic, do not describe opposing and contrasted relations between actions. Voluntary actions constitute a rather small subdivision of the whole mass of actions which, taken either together, or separately, are automatic. The cerebrum, like every other automaton, consists of mutually limiting and regulating parts, driven by an energy or energies, supplied from without. Under the same conditions its actions are the same. But the conditions are seldom twice precisely alike, so that the resulting actions differ, and become antecedently unascertainable because we cannot see what the conditions are. In fact, men have often been led to think there were no conditions, and so come to the untenable conclusion that a being thus constituted is a sovereign, and free.

The automatic action of the cerebrum is more readily perceived and admitted in the case of people of *genius*, whose mental products and physical movements are unusual, and therefore eccentric. They are said to be people deficient in will, because they are liable to unusual stimulations, and to perform actions not common to the general run of mankind; who are supposed to have a will, because their actions plod along after a stereotyped and uniform pattern, not liable to spurts and eccentricities, and therefore of a nature to be predicted and anticipated. The poet Coleridge has been mentioned as a sample genius. One day after reading the account, by Purchas, of the Kahn Kubla and his palace at Xanadu, he fell asleep from the effect of opium he had taken, and in a dream or vision the words of the poem, beginning

> "In Xanadu did Kubla Kahn
> A stately pleasure dome decree,"

came to him, and he wrote them down as soon as he awoke. This is certainly a plain specimen of automatic cerebral action. Coleridge once sold a poem he had composed and could recite from memory, but had not written down. He got his pay in driblets, but never could command resolution enough to write it out according to promise. This is quoted as proof of a deficient will, with the false idea that people with deficient wills are more automatic than others. As shown in chapter 70, the will is the resultant of motives, which in some cases reinforce, and in others tend to neutralize each other. In the former case, the will appears strong and positive; in the latter, weak and vacillating.

The organs which we inherit are very different in their degree of mobility, and our actions oftenest result from the stimulations of the most mobile. We may distinguish among the organs two classes, which can be called, respectively, the useful and the ornamental. We all have both kinds. With the mass of men, it is the former that are the most mobile, while with geniuses it is the latter. When a genius, with small activity of the business faculties, under the stimulus of starvation, makes a promise to perform a work, which is naturally an intolerable task, as soon as his hunger is satisfied, the will, which resulted in the promise, collapses with the disappearance of the stimulus which formed it, and gives place to another sort of will formed by the stimuli then present. If a man be descended from a manly and spunky race, the promise itself becomes a motive of great force in the formation of the subsequent governing will. The same observations apply to the ordinary run of men, that do to the so-called Geniuses; but in their case the active brain cells are those relating to the common concerns of life and business, or light amusements, and the sluggish and immobile cells are those relating to the artistic and ornamental side of existence. The natural tendency of the race brain is to blossom out into this ornamental quality, and if, in the distant future, it shall come to pass, as it probably will, that a few business workers can support a majority of geniuses, the business men will be reckoned as the eccentrics. The law of selection and survival of the fittest, will always, as it does now, regulate the proportions of the classes to each other and to the means of support.

The value of promises, and the importance of observing them, arise primarily and almost exclusively from men's business and social relations. It is therefore not wholly unaccountable that many who have inherited no business talent should be likewise destitute of a sense of business honor. Mozart was another of those so-called weak-willed geniuses. His resolutions and promises were of little value if their performance involved work. To compose music was not work with him, but only to write it down. He was the subject of every impulse. By some fortuitous concurrence of antenatal causes he inherited an organization which automatically and instinctively composed music. This congenital tendency ought to have been supplemented by the cultivation of a habit of industry. A well-formed habit is a "second nature." This proverb seems to recognize the essential identity between habit and congenital tendencies. Most certainly the latter are to be regarded as the result of the habits of our ancestors.

A man's actions in life are governed in three modes, congenital tendencies, acquired habits, and casual impulses. To the latter class belong those artificial stimuli which society has invented to act as restraints, prohibitions, discouragements upon certain classes of actions, and en-

couragements to other classes. If the external impulses become constant they modify the habits, and when these are well settled they modify the congenital tendencies of the succeeding generation. It is said of Mozart that the influence of his wife was a potent force in the guidance of his actions.

Zerah Colburn, when a boy eight years old, was taken to England to be exhibited. He had never studied arithmetic and could do nothing on paper, but his mental grasp of the relations of numbers was something wonderful. He could multiply or divide numbers in his head as fast as an ordinary person could write them down. He raised the number 8 to the 16th power, the result consisting of fifteen figures. Numbers consisting of two figures he raised to the eighth power. Being required to find the square root of 106,929, he immediately gave it 327. With equal facility he gave the cube root of 268,336,125 as being 645. Upon request he gave the factors of 247,483, viz., 941 and 263, which are the only ones the number has; of 36,083, he at once said it has no factors, which is true. When asked to multiply together numbers consisting of more than three figures, he usually resolved them into factors and worked with these separately. He found the square of 4,395, by using its factors 293 and 15, first squaring 293, then multiplying by 15 twice. The square of 999,999, he got by taking its factors, 37,037 and 27, squaring the first and multiplying that twice by the last, getting 999,-998,000,001. Some of his operations required some time. Thus, it had once been supposed, that 2 raised to the 32d power, plus one ($2^{32} + 1$), = 4, 294,967,297, was a prime number. Colburn, after some weeks, discovered its factors to be 6,700,417 × 641. (This discovery had also been made by Euler.) Colburn could not tell how he performed his work. His answers generally came too quickly to seem to admit of being the result of ordinary methods. Yet the motion of his lips and such hesitation as there was, indicated that some sort of cerebral action was going on, of the nature of which he was unconscious. But if we analyze the ordinary process by which arithmetical "sums" are worked out, we shall see that it contains the potentiality of Colburn's phenomenal genius. Any person can ascertain that 8 times 9 are 72 by counting nine sticks continuously from one to nine, then counting them over again, calling the first one ten, and so on till they have been counted eight times. A native of Australia who cannot count above six, could not possibly learn to multiply 9 by 8. Our children learn the multiplication table by rote, so that a knowledge that $8 \times 9 = 72$, becomes secondarily a matter of memory with them, and they remember that 72 is resolvable into the factors 8 and 9. In dealing with these numbers and their multiples, it is no longer necessary to go below them to *their* factors $3 \times 3 \times 2 \times 2 \times 2$. They thus begin their processes

above the point at which the Australian would be compelled to leave off. They can multiply 8 by 9 in their head, but if they be required to multiply 89 by 98 they cannot do it except by a process which practically first ascertains the factors of those numbers, and reduces the quantities to be handled within the limit of what can be done "in the head," so that they multiply 89 by 98 simply by operations with 9 and 8.

Such prodigies are constantly turning up. The papers have lately mentioned a boy of only six years, in Michigan, who multiplies in his head, quantities having four figures.

The Louisville Commercial, in Dec., 1889, gave an account of a mathematical prodigy of the African race, Sam Summers by name, living in Shelby County, Ky. He is a common farm hand, 34 years old, cannot read or write, and does not know one figure from another. Yet he gives correct answers to all questions in arithmetic that can be asked; such as, multiply 597,312 by $13\frac{5}{8}$; how many bushels in 70 bags of wheat, each containing 3 bushels, 3 pecks, and 3 quarts? If, after seeing a flash of lightning, you count 20 beats of the pulse before hearing the thunder, how far off is the cloud, allowing the pulsations to be 70 per minute and the velocity of sound 1,142 feet per second? All such questions as these, and many others more difficult, he answers quickly and always correctly.

Besides the mathematical genius, there are numerous other sorts, as mechanical, musical, artistical, poetical, inventive, &c., and lastly, that unclassified specimen called the *Odd* genius. In all of them cerebral operations go on, of which they are unable to give any account.

But while unusual actions attract more attention, they are not in fact either more or less automatic than others.

As pointed out in a former chapter those actions which are performed in consciousness are no less automatic than those done unconsciously, and moreover those actions of which we become conscious, result from cerebral activities of which we are not antecedently conscious. But furthermore it is obvious that consciousness itself is an automatic activity, since in any given instance it is the result of a cerebral action which must of necessity have preceded it. As an example of unconscious cerebration in a conscious state, we have the familiar case in which, after trying in vain, by every means we can think of to remember some name, date, occurrence, or quotation, we give it up, when a little while afterwards the idea we could not catch, suddenly darts into our consciousness. A person will often say, "I can't think of that name now, go on with the conversation and it will come to me presently," and it generally does. Another example of this sort of cerebral activity is seen in the way in which we absorb the meaning of a book we read. If it be of a light and ordinary character and easily understood,

we take it in as it were by sentences. If the meaning is a little obscure, we scan the words and observe their separate meanings, and get at the idea by words. If the words are new, we observe the letters of which they are composed and build up the meaning of the writer from the minutest elements. "In like manner an expert calculator will cast his eye rapidly from the bottom to the top of a column of figures and will name the total without any conscious appreciation of the value of each individual figure." (Carpenter). After we have had a subject under consideration for a time, then turned our attention from it, and after an interval returned to it again, we find it presenting new aspects, of the cerebral process for the attainment of which we have been entirely unconscious. The subject has often become cleared of difficulties in this unconscious process, which did not yield while conscious attention was directed to them. *Emotional* processes are automatic as well as those denominated intellectual. Both attractions and aversions are formed in an entirely insensible manner, and take complete possession of a person before he knows it.

Numerous cases could be cited of intelligent cerebral action taking place during the unconsciousness of sleep.

A gentleman related the following to Carpenter: "My father, when a student of divinity at Basle, was required in due course to compose a discourse for public delivery on a given text of Scripture. All power to grapple with the subject seemed gone from him; and he was for days in a state of nervous agitation, unable to deal with the matter in any way satisfactory to himself. The evening before the day of ordeal, he composed something, and lay down utterly disgusted with his performance. He fell asleep, dreamed of a novel method of handling and illustrating the subject; awoke, leaped out of bed to commit the ideas to paper, and, on opening his desk, found they were so committed already in his own writing, the ink being hardly dry."

A similar case is related of a student at Amsterdam, who was one of ten to whom the professor, Van Swinden, gave the same problem in arithmetic to work out. This student worked three successive nights on the problem, and the third night, having covered three slates with figures without success, his candle burnt out, and himself exhausted with fatigue, he threw himself upon the bed and went to sleep. Next morning, upon his writing table he found a paper in his own handwriting, containing the problem worked out in a manner much more simple and direct than the method he had attempted while awake, and the professor declared the solution was more simple and concise than any which had occurred to him. No one had been in the room beside himself, and he had done this work in unconscious sleep, and in the dark, to boot.

Another case is given by Abercrombie of a distinguished Scottish lawyer who had been consulted in regard to an important case, and studied it anxiously for several days without a satisfactory result. One night, his wife observed him to get up and take his seat at a writing-desk which was in the room, where he wrote a long paper which he folded, and laid away in the desk, and then returned to bed. Next morning he told his wife that he had dreamed out the problem he had so long wrestled with, and said he would give anything to be able to recover the train of thought by which it was done. "She then directed him to the writing-desk where he found the opinion clearly and fully written out; and this was afterwards found to be perfectly correct."

It is said that parliamentary reporters have been known to fall asleep while a member was speaking, and to continue to take down his words for a short time unconsciously, yet correctly.

An anecdote is related of a person who was sent for, to visit a friend who was dangerously ill at the house of a physician in a distant town. On his way to the place he totally forgot the name of the physician with whom his friend was. He read over a post-office directory, thinking that a *sight* of the name would stimulate the memory, but it did not. But afterwards, when his thoughts were temporarily diverted to the subject of his breakfast, the name flashed into his consciousness. He *had seen* the name in the directory without effect.

Dozens of cases like the above could be named, where things have unaccountably disappeared and have been supposed stolen or lost, when at last it will occur to the loser that he has himself laid the thing away in a particularly safe and secure place, and so recovers it.

A civil engineer once hid his leveling instrument under a big rock ten miles from town, but did not return to use it next day as he expected. A week later when he did want to use it, he had totally forgotten having hid it, and after diligent search in usual and unusual places, concluded it had been stolen by a circus troupe which had then departed to the next town. He swore out a search warrant, followed the show, and thoroughly ransacked the entire outfit, to no purpose. He had an assistant who shared the lapse of memory and the worry of the search. At last, when both were completely "beat," the remembrance of the rock returned to the assistant with the suddenness of a flash.

Oliver Wendell Holmes says, "The tree you are sticking in, will be growing when you are sleeping. So with every new idea that is planted in a real thinker's mind; it will be growing when he is least conscious of it. An idea in the brain is not a legend carved on a marble slab; it is an impression made on a living tissue, which is the seat of active nutritive processes."

Facts dumped promiscuously, as it were, into our brain, will, if left

to themselves, become arranged according to the relationships which the external objects, to which the facts refer, occupy toward each other. So that the idea when formed by this automatic process of arrangement, shall be a true reflection of the external objects just as they are, and just as they stand with regard to each other.

The saying, "I'll sleep on that proposition, and let you know in the morning," and others like it, indicate a popular recognition of the fact of the automatic and unconscious arrangement of stimuli into definite ideas. Numerous cases can be cited of thinkers, composers of literature, inventors, &c., who, recognizing the principle, habitually conform their work to it. When they come across something difficult, they first get all the facts possible, and conclude what aspect of their inter-relationships it is they want worked out, and then they leave the matter to the automatic solution of the brain; sometimes a solution is soon reached; at others, it is necessary to make frequent inquiries of the brain what progress has been made, in order to stimulate and keep up to the mark its unconscious attention to its task.

A will being made up of various stimuli, some of which influence the actions in one direction, and some in another, obviously when one set is silent or inactive, the will is formed in accordance with the other set. As only a small number of the motives which form the will, are at any one time present to the consciousness, it follows that when those motives of which we are conscious, are divided in direction so as to neutralize each other, the action may be instigated and impelled by motives of which we are unconscious. Accordingly, we often find that we have done things which we never had any conscious intention of doing. If any person will observe the gestures, movements of hands, feet, body, muscles of the face, eyes, &c., that he is constantly making, he will soon see that those of them which are involuntary, and for which he can assign no reason of which he was antecedently conscious, constitute a vast majority of the things he does. And it very often happens that a person makes gestures and movements quite different from those which were necessary to carry out his conscious intentions, and even against them. It is evident that in all such cases it is an under-stratum of stimuli, or, in other words, an unconscious cerebration which governs the acts, and consequently such acts appear to our consciousness as if they were prompted and carried on by some power foreign to ourselves, which has obtained control of our nervous organization. Unconscious muscle movement is a necessary and logical consequence of unconscious cerebration. The movement of the muscles by which planchette is made to give intelligent and often unexpected answers, is, when honestly manipulated, always unconsciously directed by ideas, of the possession of which the operator may be conscious, or which he may have

forgotten. Muscle reading also depends upon the principle that the idea which moves the muscle can form the motor combination necessary to stimulate the contraction without arousing consciousness of it. Even when we are on the alert to prevent it, our muscles of expression are very apt to betray us from the unconscious stimulation of cerebral senses. Our brain is full of unconscious or passive memories of detail which we use every hour, and could not do without. By these we go ahead and do everything, and yet we are generally unable to tell how. Who can tell how he played a Jews-harp, what muscles he moved when he spoke, or wrote, or sung, or how widely his mouth opened when he called to his friend across the street? Yet the memory of all these details of muscle movement are in the brain, or else we could never (in one trial) make the right motion to produce the effect.

A story is told of a swan which came daily at a certain hour and tapped at the door of a cottage where it received food; also a dog which was accustomed to be washed regularly, once a fortnight, to its great dislike, and which got to running away on the washing day to avoid the ordeal. We hear of horses, dogs, and other animals that know when Sunday comes. These cases show an instinctive measurement of time, that is a measurement by means of habit. We may say the swan got hungry about that time of day, and its hunger prompted the action. True, but to be hungry at a particular time of day is largely a matter of habit. Men of regular habits of occupation generally get hungry at the same time daily. This involves physiological processes which follow the same routine daily. There must be a regular succession of actions in the stomach, glands and intestines, which together complete a cycle; and when it is completed, the first term of a new cycle is reached, namely a condition of the stomach which arouses sensation. The automatic succession of the actions afford an unconscious measurement of time. That is, we are not conscious of the measurement while it is going on but only when it is completed. That the organs do thus measure time, is proved by the further fact that they can be habituated to a new routine. Thus some people eat three meals a day in summer and only two in winter. After the change is made to the winter rule there will for a while be a sensation of "goneness" about noon, but after a time this is postponed to suit the new routine. Idiots are usually strongly bound to habit and subject to the unconscious measurement of time, by the automatic routine action of organs, and become uneasy unless the same habitual performances are gone through with every day at about the same time. Sometimes a pretense of doing it will satisfy.

When a person upon going to sleep charges his brain to wake him at a certain hour, as many persons have the power to do, provided the attempt is fortified by habit, we are bound to conclude that some sort of

tally is kept in the consecutive action of the cerebral cells. The same is true in those cases of hypnotism in which the subject is commanded to sleep till a certain hour, and obeys punctually.

Akin to the automatic measurement of time, but even more remarkable, is the automatic registration of direction. All kinds of animals, from snakes up can keep tally of direction so that they cannot often be lost. This faculty is prominent among those races of men who use it a great deal, such as our Indians and Half Breeds. Peter Bottineau, after tramping with a surveyor[1] for ten miles through the woods, avoiding swamps by wide detours, was requested by the surveyor to set the instrument in the direction of the point from which they had started. He did so, correctly, as the line they ran back proved, although none of the rest of the party had thought him right by 20 or 30 degrees. He could give no account of his knowledge of the direction to the place except that he knew "because he had been there."

We all possess a great number of buried memories which are never aroused till we are assailed by some violent stimulation. A case is related of a woman who, while delirious with a fever, continued to repeat sentences in Latin, Greek and Hebrew. After her recovery she said she was entirely ignorant of those languages; but it was ascertained that she had once been the servant of a clergyman who was in the habit of reading and reciting aloud in those languages, in her hearing. She must have imbibed those memories in a semi-unconscious manner, and they remained dormant until extraordinary conditions gave them activity and motor expression. Our consciousness never extends at any one time to any considerable number of our ideas, seldom even to all those related to the subject which may engage our attention. After a will is made up, it is liable before it can be executed to be altered by a belated stimulus from a half asleep cerebral organ, one which may have been in unconscious abeyance for a long time.

We are seldom ready to say what our idea or opinion upon any matter is, and if we give an expression, we immediately become aware of its incompleteness or inaccuracy, from new considerations which flow down from the internal senses and reveal their existence to full consciousness for the first time.

No doubt the feeling of inspiration which has come to a great many people in times past, has arisen from the unconscious automatic action of the internal senses, the results of which have come into the consciousness with a startling suddenness, which made it seem like a revelation from some other intelligence.

A gentleman related the following to Carpenter: "When at school, I was fond of trying my hand at geometrical problems. One baffled me

[1] Lewis Harrington.

I often returned to it, in fact kept by me an elaborate figure. Some years after, and when the problem had not been touched by me for some time, I had been sitting up till the small hours deciphering a cryptograph for one of my pupils. Exulting in the successful solution, I turned into bed; and suddenly there flashed across my mind the secret of the solution of the problem I had so long vainly dealt with, this secret being a slight addition to my elaborate figure. The effect on me was strange. I trembled as if in the presence of another being who had communicated the secret to me."

Dr. Bushnell is quoted as saying: "There are two sorts of influence belonging to man; that which is active and voluntary, and that which is unconscious; that which we exert purposely, or in the endeavor to sway another as by teaching, by argument, by persuasion, by threatenings, by offers and promises, and that which flows out from us unawares to ourselves." These insensible influences come honestly from our real character, while those exerted in consciousness and with a purpose, represent motives in which there is a large admixture of stimuli direct from the environment and our social conditions, and which we have not yet, and may never incorporate in our character.

It is his subjection to these two sorts of stimuli that enables a man to be a hypocrite. He may perform praise-worthy acts from motives of a temporary and superficial nature, instead of from principle.

Oliver Wendell Holmes says: (Mechanism in Thought and Morals) "Our definite ideas are stepping stones; how we get from one to the other we do not know; something carries us, *we* [*i. e.*, our conscious selves] do not take the step. A creating and informing Spirit which is *with* us, and not *of* us, is recognized everywhere in real and in storied life. It is the Zeus that kindled the rage of Achilles, it is the Muse of Homer; it is the Daimon of Socrates; it is the Inspiration of the Seer; it is the Mocking Spirit that whispers to Margaret as she kneels at the altar; and the Hobgoblin that cried, 'Sell him, sell him,' in the ear of John Bunyan; it shaped the forms that filled the soul of Michael Angelo, when he saw the figure of the great law-giver in the yet unhewn marble, and the dome of the worlds yet unbuilt Basilica, against the black horizon; it comes to the least of us as a voice that will be heard; it tells us what we must believe; it frames our sentences; it lends a sudden gleam of sense or eloquence to the dullest of us all; we wonder at ourselves, or rather not ourselves, but at this Divine Visitor who chooses our brain as his dwelling place and invests our naked thought with the purple of the kings of speech and song."

Many a prophet and seer has thought he recognized in this voice within him, a veritable message from a supernatural power, and has honestly and undoubtingly given to the world, as a divine oracle, that which in reality

was nothing more than the product of his unconscious cerebration, the interacting of his internal senses.

It is true enough that the elements of this wonderful voice come from our environment and originally are not "*of*" us. But the meeting of these elements took place in our brain, and for the first time in the universe, by their interactions in our cerebral sense organs, was that voice developed and built up, like our audible voice, with its peculiarities of timbre, its clangs and harmonics, which make it different from any other voice that ever was or ever will be. If anything about us is *of* us, if the expressions of our faces are ours, then so is that internal voice.

We are all of us like two persons secretly connected with each other. The one is the small part of our internal senses which is in conscious activity at this moment reinforced and modified by new sensory stimulations. The other is the great body of our internal senses which work away in silence. Neither of these remains the same for two consecutive minutes. The activities of the first are recognized in a succession of sensations; those of the last flash into consciousness only upon the stimulation of a special occasion.

Sometimes when a man does something unusual and unworthy, it is said of him, or by him, that "he was not himself" on that occasion. The fact was, he *was* one of the selves which constitute his entirety, but not the one he commonly prefers to exhibit. Under the overpowering influence of unworthy external stimuli he may have acted in a manner which gives offense to his inner better sensibilities; or in the temporary absence of usual worthy external stimuli, the internal *bad* character has had a momentary chance to assert itself and instigate an improper act. When a man acts in an insane and outrageous manner, we sometimes say "he is beside himself," as if we instinctively recognize the fact that there are two of him, and that the one "beside" him, freed from usual restraints, is now asserting himself.

We conclude then that *all* action of the cerebrum is automatic or reflex; the definition, *reflex*, applying to those actions which involve but little or nothing more than the direct motor apparatus of the cerebrum skipping the modifying influences of most of the cells of memory registration; and the term automatic properly applying when the action does receive in considerable part the modifying influences of the cells of memory registration. It is obviously difficult to draw the line between the reflex and automatic action of the cerebrum. Both sorts originate at first in sense impressions from the environment. Some of these impressions carry their influence into the memory cells, and there it stops in the re-erection of old memories or the differentiation of new ones. Some of them go on to motor action of muscles. The very same sort of an impression may at one time do one of these things and at another time the other one. It may do both.

The automatic action sometimes originates when there is no apparent external stimulus, the immediate stimulus being a memory of a former impression, or a new mental state brought about by the condensation and co-ordination of several former impressions. This is perhaps the most really automatic cerebral action, but it is obvious that this action is not essentially different from the other; the pause or break that takes place between the incoming of the external stimulus and the outgoing of the motor stimulus, is occupied by invisible, intangible and unconscious operations, which are the necessary links in the chain of causation from the original sensory impression to the final motor action. Automatic action may therefore be properly defined to be *delayed and modified* reflex action. The greater the delay, the more automatic it appears.

The cerebrum is indeed the reflection and representative of the "without." It has been well named the microcosm, for it possesses in its structure the potentiality of reflecting the nervous equivalent of every ray of energy which has been darted upon it from the macrocosm without. And its reflected energy is directed upon the same motor centers, which, during its inactivity, are moved directly (reflexly) by the stimuli from the environing macrocosm.

I have in this chapter taken no account of the telepathic sense, or the telepathic acquirement of ideas (the subject of chap. 79), because an idea injected into the brain by telepathy becomes a part of the sum of environing stimuli domiciled there, the same as a sermon poured in at the ear, or a printed tale, or an acted drama taken in at the eye. It matters not to my argument how much we may be influenced by telepathic stimulations, or whether we are influenced by them at all. The actions resulting from such influence would be ours in the same sense that actions influenced by an eloquent oration would be, or for that matter, by any other motive big or little, worthy or unworthy. It does not alter the case of the automatism of our action whether it be instigated by a Zeus or Dæmon outside of us, or the potent suggestions of an empty stomach inside.

CHAPTER LXXVI.

REASON AND INVENTION.

In studying the nature and essence of Reason, we need not look for any principles in addition to those already set forth. All nervous and cerebral action is merely the continuation of motion begun in some form in the environment, and continued through the organism, modified by the reaction of the internal sense organs or other parts of the nervous

system. Reason, in the ordinary sense, is merely one aspect of this nervous action, as instinct is another aspect. In the wider sense, all the cerebral processes above mere sensory impressions and reflex actions, are reasoning processes. There is no physiological dividing line between perception, ideation, instinct, invention, prediction, &c., but these may all be included under the head of reason. All the processes which lead to volitions, and which excite the emotions, are essentially reasoning processes. All those in which new incoming stimulations are automatically shunted upon the tracks traversed by similar stimulations which assailed the brain in former times, are reasoning processes. This particular aspect of them is called perception, and it involves the automatic comparison, in some particular, of the new stimulus with one or more old ones. It needs no proof that perception is automatic. If a savage is brought into the city, and for the first time hears the sound of a bell, he does not know what it is. Let him see the swinging of the bell, and hear its peal at the same time, and the association of the two as objective realities, will cause in his brain a differentiation of two cells or organs sustaining to each other a relationship corresponding to the sight and sound of the bell. If he hears the bell again to-morrow, there is an automatic comparison of the sound with that heard before, and the perception is completed that it is the sound of the bell. Now this, although automatic and unavoidable, is as true reasoning as the most complicated examples we could name. Our brain having become differentiated to the various sounds of bells, musical instruments, steam whistles, voices, and cries of men or beasts, the click of telegraphs, and the ticking of clocks, by this process of reasoning we are able to identify any one of them. We instantly say, "There goes the bell," "I hear Smith's voice," "I hear the clock strike," &c. The perception involved in the expression "I hear the clock strike," includes the association of a new sensation with a revived memory, hence a comparison followed by identification, and a sense of the relation of cause and effect. We have, therefore, in this simple perception the elements of several departments of reason, some of them the highest, and yet such reason is exercised hourly by every robin and every mouse.

All reasoning includes a perception of the relationships of things. Perception is usually a comparison of a memory more or less old, with one arising from a sensation just now experienced; although sometimes the term is used to express a new comparison of memories both of which are old. In any case perception is based upon memory, and therefore reasoning is based upon memory. No animal can possess reasoning powers, if it be destitute of internal sense organs, or memory organs. And, on the other hand, it is equally certain that any animal possessed of memory is endowed with reasoning faculties. The possession of one

memory implies the possibility of two, and two memories of related things or of the same thing, involve perception and comparison. The simple fact that objects in nature are associated with each other, involves the necessity that the sensations of those objects impressed in the brain should be in like manner associated. The ability to see a tree includes also the ability to see the ground it stands on. The sensations of these two contiguous and related things being constantly formed together in the sensorium, it may happen that any stimulation which revives the memory of one, will overflow to the associated organ and revive the memory of the other. The two memories taken together constitute a single rational idea ; rational, because the sensations and their memories truly represent the relationship which the objects bear to each other. When this relationship is not truly represented in sensation, or memory, the idea is incorrect and unsound. It is in fact irrational, whether its defect arises from partial or false impressions on the sense organs, or from a partial or total failure of the revival of the memory of the sensations. Reason, therefore, is the nervous equivalent of such of the modes of energy as are reflected from objects in our environment, and assail our sense organs. It is the reflection of the environment. It is, so far as it goes, an imitation of external nature. The completeness of the imitation obviously depends upon the number and variety of the sense impressions obtained from the objects imitated. Thus, a person from seeing a tree and the ground it stands on, may get a correct idea of the fact that the tree depends upon the ground for its mechanical support, but without further sense impressions he will know nothing of the roots or of the flowing sap, and if he be color-blind, he may not perceive any difference in color between the leaves and the bark. Our perception of all things, must, in the nature of things, be limited and incomplete in number and variety, and yet in many, and we flatter ourselves in most cases are correct as far as they go.

But it is evident that the greater number and variety of sense impressions we have of any object which serve to furnish us with associated ideas of its related parts, or of its relationship with other objects, the more comprehensive, correct, and rational will our ideas be of such object and its relations. One of the essentials of a comprehensive view of associated objects, is a capacious place for the storage of the sense impressions. The cerebrum constitutes this storage room in all the vertebrates.

The relative size of this organ in the various animals is a fair gauge of the number of memories which, under proper exposure to sense stimulation are possible to them, and consequently of the number of rational ideas of which they are capable. An animal with a limited cerebral capacity has fewer memories in association with each other than man

possesses, but these associated memories may as truly represent the particular association of the external objects for which they stand, as do the associated memories of man. The lower animal may perceive that A is related to B, C is related to D, and E to F. The man may perceive these relationships, and may observe further that A is related to C, and D to E. Thus any simple perception is truly an act of reason, and it may be simply reinforced and not set aside when new perceptions are added to it. Consequently the acts of animal reasoning may be true, as far as they go, just as man's may be true as far as they go. Those of the animal are few, compared with those of man, while man's actual perceptions are few compared with those which are possible; and those of one man may be few compared with those of another.

It is true that man knows but little compared to what is knowable, but knowledge is a mere delusion if the fundamental principles, we suppose ourselves to have discovered and verified, are to be subverted as soon as we learn a little more. These immutable principles which we have discovered are not numerous, but it is not unreasonable in us to stand by them, carefully discriminating between what are really principles and what may turn out to be merely details and particulars.

Maudsley says that "it is absurd to suppose that there is nothing outside of human experience different from human experience, nothing beyond the actual or possible reach of human faculties," and equally so to dogmatize and affirm positively what that outside something is. True, and yet it is perfectly legitimate to judge all departments of nature by the general principles which we find in that department of it accessible to us. Thus we may confidently assert, that there is no part of the universe in which two and two make five, or in which the inscribed angles of a triangle are not exactly equal to two right angles, or in which dimensions of bodies are more or less than three.

Every human idea is founded upon elements derived from human environment. The elementary stimuli are but partial and distorted representations in many particulars, and the ideas founded by them may be more or less incomplete or incorrect; but whatever they are, they never rise above their source. Our ideas are all ideas of *natural* things, no matter how distorted and false, and when we imagine they bring us into the presence of the supernatural, we may know that we are being deceived, and every idea of the supernatural we can possibly have is certain to be false; that is to say, it is in reality an idea derived from nature and represents only relationships of things in nature.

The idea of *Cause* and *Effect* is involved in the greater number of animal perceptions. The timidity of animals has arisen from the observation of effects unfavorable to themselves, resulting from certain phenomena. Wild horses, deer, and other animals run before a prairie

fire, not on account of physical pain inflicted by the fire, but from terror of pain anticipated. Anticipation can arise only from memory. They anticipate injury only because it has been experienced from the same cause in the past either by themselves or some of their tribe. Here is a definite idea of cause and effect. A savage man perceives this relation of fire to the destruction and pain of his body, and his perceptions go further, for he can produce fire by violently rubbing two dry sticks together. He perceives the relation of cause and effect between his exertion and fire. The modern civilized philosopher and chemist has carried his observations still further, and will tell you that the heat which sets the sticks on fire is a new form of the motion of rubbing, and that the blaze is the result of the union of oxygen with the disintegrated carbon of the sticks. The conclusions of the last observer do not invalidate those of the former ones. They simply extend to relationships not perceived by the former observers. The recognition of Cause and Effect arises when we experience, several times in succession, a group of sensations, always occurring together, which bear to each other a constant relationship of antecedent and consequent. The *repetition* of the experience gives sensations of uniformity and constancy, and hence necessity, and these are involved in the recognition. It is easy to fall into error when sensations of things not really related occur together in our sensorium, and it is equally easy to miss such relationships when the sensatioins are separted a little from each other. Thus every savage can perceive the connection between sunlight and the sun, and moonlight and the moon, but further observation is required to connect moonlight with the sun.

The perception of cause and effect is by no means a peculiarly human faculty, but it is a property of every animal brain; the extent and variety of the perceptions depending directly upon the size of the cerebrum. As all our perceptions are founded upon sensations, it follows that the final proofs of the truth of a conclusion of reason are derived through the senses, and are in fact sensations. The only guarantee we can have that any sensation is a correct transcript of an external object, is the supporting testimony of more sensations. A skillful painter can represent a ball on canvas so that from a certain standpoint the eye may be deceived into reporting it a ball. But if the point of view be changed, or if the sense of touch be brought in to make the test, new sensations are aroused which correct the first one. It is so in all reasoning. All demonstration consists finally in an appeal to the senses. It may not always be necessary to carry the appeal so far. It may be sufficient to go only as far as the memory of things.

The science of geometry, for example, is founded upon a lot of axioms and postulates; an *axiom* being defined as a self-evident truth, and

a *postulate* as a problem whose solution is self-evident. A theorem in geometry "is a truth requiring demonstration." Axioms and postulates are things which are perceived as soon as seen. For example, it is an axiom that the whole is greater than a part; another, that a straight line is the shortest distance between two points; again, that things which are equal to the same thing are equal to each other, &c. These propositions are *seen* to be so, and the *seeing* is the end of the demonstration. Nothing can go beyond it. The demonstration which a theorem requires, is such a picking to pieces, or analysis, that the parts can be seen. It is a reduction of the theorem to axioms. For example, let it be demonstrated that *in any triangle the sum of the three angles* is equal to two *right angles.* Let X, fig. 380, represent any triangle; then the angles $a + b + c$ equal two right angles, or 180 degrees. Produce the sides C and D so as to form the external angle d opposite b, and draw E through O, parallel with the side C, and produce the side A to B. All the angles which it is possible to construct about a given point, as O, must together equal the circle, or 360°, or four right angles, and any straight line, as A B, passing through O, must split the circle exactly into equal parts, so that the sum of the angles about such point on one side of such straight line will equal 180°, or two right angles, therefore $c + e + f =$ two right angles. The lines C and E being parallel, they must meet A B at the same angle, so that the angle $a =$ the angle f; C and E also meet D at the same angle, consequently the angle $d = e$. But d is equal to its opposite angle b, so that $b = e$. Consequently a, b and c being equal to f, e and c, they are equal to two right angles; *which was to be proved.* Thus, this theorem, not obvious at first, as a whole, is found to involve a number of propositions, each of which is obvious to most perceptions. But if one should hesitate to admit some of the assumptions, as, for example, that the opposite angles, d and b, are equal, that proposition becomes a theorem, and may be further reduced. Let a figure (381) be constructed by drawing two straight lines across each other so as to form opposite angles. Then will the sum of the angles g and d equal two right angles; g plus b will likewise equal two right angles: $g + d$ therefore equals $g + b$. Now, if g be taken from each of these equal quantities, the remainders will be equal; that is, the angle d will

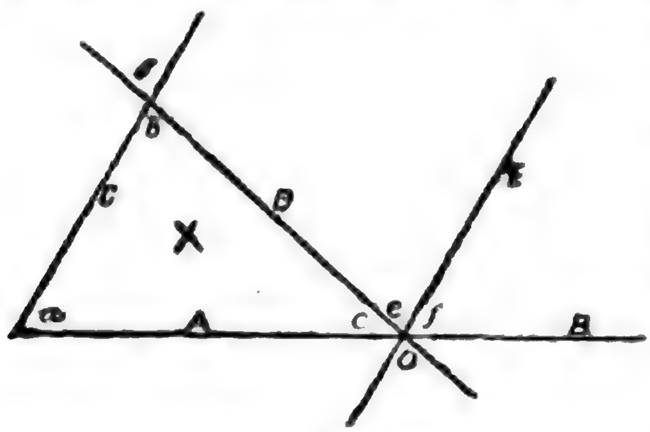

FIG. 380.

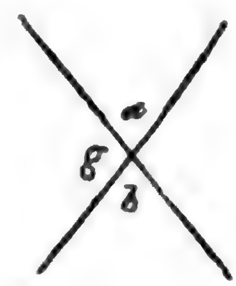

FIG. 381.

equal b, *which was to be proved.* If any question is raised as to such result of taking away g, the geometer says the proposition is an axiom, that when equal things are taken from equals, the remaining things are equal, and he cannot prove it any further. But if you cannot *see* it in the present form of statement, it may be illustrated in some other way. If a boy has five marbles in one hand, and an equal number in the other, and you take two from each hand, he will have still an equal number in each hand. This is obviously no reduction of the proposition, but only another view of it, and if the student cannot perceive it in some such form, his cerebral equipment is not adapted to the apprehension of mathematical perceptions. And this, I take it, is equivalent to saying that the sensation made by one of the equal qualities is not retained in the sensorium long enough to allow the second one to make its sensation during the continuance of the first, and so the duplex, or rather compound sensation which constitutes perception is not experienced. Scarcely any normal human brain would be unequal to so simple a perception. It is almost, if not quite, as simple, and of the same sort as a perception of motion in a moving body. We see the body in a certain place, and before the sensation caused by such view is dulled by the relapse of the erethism of the cells involved, a new stimulation supervenes, of the body in a new position. It is the lapping over, or superposition of each of these slightly differing sensations before its predecessor has faded out, that gives the perception of a new quality, a continuously changing relationship which a single instantaneous sensation could not give.

This will be more readily appreciated when it is considered that a wheel revolving so rapidly that its spokes cannot be distinguished will, if illuminated by an electric discharge, appear as a wheel standing stock still. In this case the duration of the electric spark is too short to admit of more than one sensation, and there being no succession of sensations there is no perception of motion. It thus appears upon analysis that every perception, and finally every act of reasoning based upon perception, may be traced to simple sensation and sense impression. J. Stuart Mill says, "All inference is from particulars to particulars. General propositions are merely registers of such inferences already made and short formulæ for making more." "There is a *petitio principii* in every syllogism and nothing is really proved by one. Thus to say, all men are mortal, Socrates is a man, therefore Socrates is mortal, the conclusion is assumed in the premise and included in it, not proved by it." What we really do in such a form of speech is not to prove something, but to predict something. A prediction is simply a recollection in association with an idea of futurity. Our prediction that Brown will die is the recollection of the death of other men applied to our idea of Brown. Our recollections of Brown's life

thus far are similar to the recollections we have of other men in regard to the general essentials of existence. But we recollect further that other men have finally died and this recollection we use to piece out the recollections of Brown's unfinished history. As he is still living this last part of the tale is of something still to come, and is therefore not only a memory but also a prediction. Every act of ours involves a prediction. The present act is an imitation of an act or parts of acts that have been performed before. The recollection of the former act is the guiding manual for the production of the present one, and it is prediction as to the parts of the new act not yet carried out. It has been remarked by somebody that *prediction* is the highest form of reasoning. The ability to tell what is to happen from data derived from the past and present when it has been applied to unusual things, has often excited admiration and wonder, and seemed almost to justify the apotheosis which many have been willing to accord to Human Reason. The case of the discovery of the position of the planet Neptune in 1847 by the astronomers Le Verrier and Adams has often been pointed to as a superlative example. The planet Uranus was discovered by accident. The path of every planet is more or less disturbed by the influence of the other planets of the system. When the orbit of Uranus was fully marked out for it by the astronomers, due allowance having been made for every influence they could think of within the solar system, it was found by observation as it slowly plodded around its 84 year track, that it deviated considerably from the caculated path. Having exhausted inquiry within the then known system without finding the disturbing element, the astronomers naturally concluded it must lie without. And knowing that planets disturbed each other's orbits in the manner in which this was disturbed, they concluded there must be another planet outside of the orbit of Uranus. There was nothing at all extraordinary in this conclusion except the magnitude and dignity of the subject under consideration, although for that matter a man may shoot a whale as easily as a squirrel if he is not afraid to try. If a half-breed trapper finds one of his traps demoralized, the bait abstracted, and the neighboring ground indented by strange and unfamilar tracks, he comes to the conclusion that some new animal outside of the circle of his acquaintance has been there and done the mischief, and he contrives some new apparatus by which to ensnare him, and perhaps lies in wait all night besides. From a comparison of the operations of the animals he knows with those of the unknown, he conjectures the character, nature, and strength of the latter.

So our astronomers, being familiar with the performances of certain planets of their acquaintance, naturally attributed to an unknown planet, performances which were every way like theirs, but which none of them were

in a position to execute. There was certainly in this conclusion nothing to excite surprise in any one having an inkling of the general facts of the case. It seemed more wonderful that the mathematicians were able to calculate the position of the stranger in the heavens with such accuracy that it was actually found within one degree of the place indicated. But here again the most obvious analogies were followed. According to Bode's law, the new planet should be almost twice as far from the sun as the planet Uranus, and in making their calculations the astronomers assumed the correctness of the law. It was afterwards shown that in this case Bode's law signally fails, since Neptune is not so far from the sun by 758 millions of miles as Bode's law would make it. It was, therefore, after all, mere luck that this enormous error in their assumptions did not throw the calculators entirely off the track. They happened to take their observations at a time in the revolution of the planet when the assumed distance gave it nearly the same direction from the observers as the correct distance would have given.

If the discovery had remained to be made 40 or 50 years later, when the planet was in a different part of its orbit, the assumption of the erroneous distance would have thrown them wide of the mark, because the relative positions of the planet, then due to the assumed orbit and to the real orbit, would have differed far more. So that the discovery after all was, as remarked by some mathematicians, the result, to a large extent, of a happy accident.

Invention involves prediction, and both rest upon memory. From the memory of things experienced and seen, particularly those things which have recurred often and regularly, we predict future recurrences. And the more facts we have in memory relating to anything, the more confident we become of the predictions we make concerning it. A savage will predict a to-morrow and a next year, purely from the experience of yesterdays and years gone by. He cannot give any other reason for it. But a man of science makes a like prediction based on a more extended knowledge of related facts. He knows better than the savage the past repetitions of the days and years, for he has the testimony of recorded history going back far beyond the traditions of savages, and he has, besides this, the observations of himself and others of the phenomena of the motions of the earth on its axis and in its orbit, and these, he perceives, are indissolubly associated with the recurrence of day and season. Discovering nothing likely to disturb or terminate these motions, he may be more confident than the savage in predicting the indefinite recurrence of the daily and annual periods. Knowing from past observation that certain phenomena are always seen together, we come to regard them as related, and when one appears we are reminded of the other, and look for its appearance also.

When our perception becomes sufficiently acute and comprehensive to recognize which related fact is subsequent to and dependent on the other, such perception enters into the composition of the will in procuring the things we want. A beaver will build a dam in order to have a pond. A man will work for a dollar, which he can neither eat nor wear, in order to have it to exchange for food or clothes. A buffalo will travel miles to reach a spring of water, and a cow will lift a gate off its hinges in order to gain access to the garden. In the will lying before all such acts, there enters a perception of things in their relation of antecedent and consequent, or cause and effect. As observed above, prediction or prophecy necessarily enters into the formation of every will. All our acts are based on a conviction that there will be a certain state of things in the future. If we make our plans for to-morrow, we thereby predict that there will be a to-morrow, and that there will be a state of things into which our intended action will fit. In fact, our intended action is based on the prediction, together with some emotional motive. It is in reality the outcome of these, and stands in relation to them as the effect of a cause.

All our reasoning processes, based as they are upon memory, are also processes of *imitation.* That is, the train of reasoning, whatever the subject may be, is a reproduction and expression of the memory of things seen or otherwise impressed upon the internal sense organs. Such *imitation* is seldom or never perfect, even when we wish it to be, and to the extent that it is imperfect it becomes *invention.* The facts as they stand in external nature or the environment, constitute the original pattern for imitation in the organs of internal sense. The faulty and incomplete copy of this pattern which we get in the brain, does not long remain the same, and if we try to recollect it, we can seldom get a perfect reproduction of it, even when there is strong motive for doing it. That is, we did not see the thing perfectly in the first place; and, secondly, we cannot remember perfectly how we did see it. The memory of one thing is almost certain to become involved and confused more or less with that of another, the outcome of which is something *Original.* Thus, we are more or less original when we do our best not to be. When we are indifferent to the outcome, as in the ordinary run of our waking thoughts, or when engaged in light conversation, or, most of all, when dreaming, the indiscriminate mixture of images produces the highest degree of originality. When there is a motive or purpose for the production of some special end, such motive becomes an element in the cerebral action, and fixes attention on such details of the chaotic mass of images and scraps of memory aroused by our cerebral activity, as harmonize with it; thus forming a new and coherent series, to which, as a whole, we give the title of invention. Obviously no single detail

of such invention is original. It is an imitation; a copy of something seen in nature or art. But, as a whole, the invention may be original in the sense that the details of it were never before in the same relationship to each other. It is obvious that in the falling together of unrelated images, there will at times be formed a combination useful and worth preservation. It is well known that many inventions, and some of them of the most useful kind, have been purely accidental. In fact, it is hardly asserting too much to say that they are all, in some sense, accidental. The most that an inventor with the most earnest purpose can do is to put himself in the way of the accidents.

There is an implement for digging post-holes, the "invention" of which is an illustration in point. The old-fashioned wagon wheel hubs were bound at their outer end by a wide, thin band or thimble of iron. Such a band had accidentally come off an old hub, and was for a long time kicked about the barnyard, till finally its sharp edge becoming pressed into the ground, it was quite buried. In cleaning up the yard, it was observed and pulled up, bringing with it all the earth inside of it, thus leaving a cylindrical hole in the ground six inches in diameter, and five inches deep. Here was an obvious suggestion. If the band could be again sunk in the bottom of this hole and pulled up, it would bring up five inches more of clay, and thus the hole could be sunk indefinitely. Accordingly, a handle was rigged to the band, and a patent for the "invention" taken out. Subsequently, the band was accidentally cracked longitudinally, and being used awhile in that condition, and afterwards mended, it was discovered that the crack improved it, giving an elasticity, which allowed it to hold its load better, and to be emptied more easily. The enterprising inventor would be entitled to an additional patent covering the crack, though I do not know whether he applied for it or not.

FIG. 332.—Post Hole Digger.

Nature is constantly exhibiting object lessons and throwing out hints of new methods by which man can lighten his work. But the new thing to be done must be exceedingly like an old method, and the step between the two must be extremely short, or else it will entirely escape observation. Take the art of printing, for example, an art that has made 100 years of the life of the race of more value than 1,000 without it. For thousands of years men had been writing. Nature had furnished numerous hints of the way they might shorten the labor of this writing. Savages pursued their game, or gained knowledge of their enemies by reading the printed characters they left on the ground in foot tracks. Every horse and camel printed as he walked. Dirty, or

smirched hands had innumerable times left their shapes on other objects. It was at last discerned that an illiterate king could print his name with a seal, when he could not write it. With such hints before their eyes for two thousand years, men nevertheless, continued to copy their books with slow and costly manual toil.

When we consider how great their need was for this art, when we consider that all the mechanical principles necessary for its performance had long been familiarly known, that those required to be applied were few, and their application exceedingly simple, we must be far more struck by man's stupidity than by his fertility of invention.

Cotton has been cultivated certainly for five or six thousand years, and has been almost the only material for clothing possessed by numerous nations. It has always been a most serious task to separate the cotton fiber from the seed. For the five or six thousand years in question, men did this by hand, and to pull the seeds out of two pounds of fiber made a day's work for an active man or woman. Men had possessed saws for at least as long a time, and were familiar with their use and action in pulling out woody fiber from a board, or stick of wood. But it seems never to have occurred to anyone during all these ages, that they might reduce their labor in getting their clothes several hundred per cent. by applying the saw to pulling the cotton fiber away from the seed. It only needed that the saw teeth should draw the fiber through a crack too narrow to allow the seed to follow. So obvious and simple is this, since Whitney has shown it to us, that we can only be astonished at the dense and costly dulness of perception that so long ignored it.

Numerous examples might be cited to prove that all new inventions are adaptations of old instruments, or at least, of old principles, to new purposes ; and the amount of the modification of the instrument is seldom very great in any one case or by any one individual. And it may be truly asserted that every new association of ideas, under the influence of which experiments and adaptations are made, is brought about by causes extrinsic to the inventor and so far as he is concerned, purely accidental.

The growth of all machines is an evolution, and if they be great and complicated their growth is slow, and passes through many stages of development ; and they receive improvements and alterations from many hands, and usually but small ones from any one.

Original scientific discovery is accomplished simply by the investigator putting himself in a condition to see whatever there is to be seen. He does not know beforehand what that is to be. So far as he is concerned, the discovery is accidental.

A few individuals have made what are called extensive discoveries of

scientific facts. But if we compare the work of any one man with the aggregate of discovery, we shall see that it is infinitessimally small. The great aggregate of human knowledge is due to the vast accumulation of minute contributions from individuals of many races and many generations. Each student to-day, thanks to the art of printing, has before him the results of the investigations of those who have gone before, and of his contemporaries in every part of the world. Having knowledge of all these, he need not waste his time in fields which have already been explored. If every one were compelled to begin at the beginning, and to get his knowledge direct from nature, we should forever remain in a state of barbarism. The scientist of to-day has but two hands and two eyes, just as his savage ancestor had, but he has the help of 10,000 eyes, hands, and brains to supplement and reinforce his own. If the scientist writes a book on his favorite hobby, it is usually a very small one if it contains no more than his original discoveries.

But whatever these original discoveries are they cannot be anything more than the formation in his cerebrum of perceptions of things in nature. All the scientist does is to put himself in a position to be a mark for the reflections of energy, in the shape of light, sound, odor, &c., from the body to be examined, and in saying he "puts himself" in such a position, we really mean that he *is put* there, by the reaction of some external stimulus upon his internal sense organs, which organs, as we have seen, are themselves the product of former external stimuli. So that after all, discoveries are simply manifestations to consciousness of external energies, and are in fact such external energies in new forms.

The author too is called an inventor. The man who has mastered a library is a learned man, and that means simply that a number of other people have told him the things they have seen, or heard, or found out. A man gets the credit and applause of his neighbors if he has spent his time in listening thus to what the rest of mankind have to say of their experience and observations, and they call him learned, though he may never have made an original discovery. If the learned man should write a book, it will consist chiefly of elements drawn from that library, modified by opinions and observations gathered from his personal contact with the men of his own times and place. Obviously in all this he has created nothing whatever, neither the ideas he has got from his books, nor those obtained from his neighbors, nor yet those facts, if there be any such, which have impressed themselves upon his senses from environing nature. Nevertheless these facts may be original in the sense that they were never before observed and recorded, and the book may be called original if the parts of it are so arranged as to give rise to ideas not before entertained. But as already observed, the originality is due to extrinsic influences.

Precisely the same observations apply to the so-called invention of the Novelist. He copies with greater or less accuracy a certain class of facts seen in connection with human action and character. He is in the same position as the inventor of machinery, except as to the class of external objects to which his attention is subjected. His invention consists in new arrangements of detailed facts, forming a new group representing something possible or impossible as a whole, but not in actual existence.

The Artist, again, is another imitator of external objects, reproducing his imitation in his own peculiar way. If he is an inventor as well, his productions consist of copies of actual details, placed in new and factitious relations to each other. Such relations may result from the accidental revival simultaneously of the memory of unrelated ideas, as it happens in dreams and unpurposive waking fancies, or they may be formed in accordance with a definite stimulus from the environment and result in a coherent purposive original creation, so-called.

Imagination is a process of reasoning which consists in taking parts of different ideas and from them constructing new ideas, which, while they are not true in fact, may be true in potentiality. They are factitious. Writings of fiction, studies in painting, sculpture and other art belong to this class. They differ from dreams, in being under the domination of some persistent external stimulus which selects and preserves a consistency and congruity between the parts, not usually found in dreams. *Works* of fiction are preceded by more or less complete *conceptions* of what is to be done. Conception is the name of the sensation of the subjective process and the result of the analysis and synthesis going on in the brain, which may end in the motor activities required for the production of a work of art. But many a conception ends subjectively and is never realized in any objective form. It remains as a new combination of ideas of external things. It may relate to any subject, as art, morals, science. It is to conceptions formed often in the most haphazard way that we are indebted for discoveries in science and machanics. Such accidental conceptions are very much like those accidental combinations in mechanics which prove to be useful, like the post-hole digger described above, and which thereupon become valuable "inventions." When one part of a compound idea becomes stimulated, the stimulus naturally overflows to the associated parts, and these present themselves likewise.

Association includes the parts related in memory, such as relative size of one to the other, similarity or difference of form, texture, composition, color, relative position of parts.

Comparison is that kind of association, which, ignoring contiguity, brings into a single idea two things, which, by possessing some common

quality of form, texture composition, &c., suggest each other. Also when one body thus suggests another, it produces a further suggestion of the things which accompany it, and these things will be apt to become suggested by the second body as if attached to it. Thus the Chippeway Indian, who was accustomed to salt and to *brown* sugar, thought the *white* sugar he was presented with was salt, and imagined the donor was playing a joke on him in persuading him to eat it. White granulations, to him, were associated with a saline sensation. Comparison takes place when several memory organs are stimulated at once, by which process parts of each revived idea are brought into relation with parts of other ideas. These new combinations give rise to new sensations, which will be sensations of the *contrasts*, or of the *resemblances* of the parts of old ideas thus brought into relationship.

Abstraction is that subdivision of comparison by which one quality of an object is considered apart from other qualities, and by which qualities and relationships become apparent, which are common to many other bodies.

Language, which is an expression of ideas, constantly deals in comparisons, and its study shows to how great an extent our ideas consist of comparisons. We use the word *head* to signify the top end of a man, and by comparison we apply the word to a great many other cases, as the head of the bed, coffin, street, river, mast, procession, &c. As the head is the governing part of the body also, we apply this idea in another lot of comparisons when we say head of the state, church, army, &c. Cap is a cover for the head, which is the subject of comparison when we speak of a cap of snow on the mountain, a cap sheaf on the shock, the cap timber of a trestle. We cannot describe our sensations except by comparisons. Thus, *occur* means to run against; and and when a person says a thought *occurs* to him, he compares it with something which runs against him.

Identification by comparison is the observation of similarities extending to *all* the parts and activities; as in the case of Franklin and his lightning. An obvious similarity in the noise and flash between the electric spark and lightning, suggested as also belonging to lightning the other qualities that belong to electricity, such as capacity to be stored in a Leyden jar, &c.

Classification and *Induction* consist in considering together those things which resemble each other in some essential particular, as in the classification of quadrupeds to include all that go upon four legs, &c.

Judgment is one of the subdivisions of comparison, and consists of the allotment of a new fact to its proper relationship in one of the lines of sequences or standards described in chapter 65. There is implied in judgment a hesitation in the automatic harmonizing or classifying of the

new fact with its standard, such as to allow of a continuous sensation of the process. It therefore involves attention.

There is no generic difference between a Judgment and a Prejudice. The former degenerates into the latter in proportion as the number of standards to which the new fact might be referred, is diminished. Where there is but one standard to which the fact can be referred, such reference is a foregone conclusion, and its assignment occurs without much friction or hesitation, and while it is a judgment it is also a prejudice. It is a prejudice, likewise, when any one standard in a constant state of attention monopolizes references, which in divided attention might be directed to other standards, and operate perhaps as a suspended judgment, at least temporarily.

Generalization is a process by which the properties common to several objects, serve to suggest those objects as belonging to a class or genus. It is akin to classification.

The *physiology* of these various processes is essentially the same throughout, and consists in the automatic direction of attention and blood supply to the several organs. In all probability the excitement of one organ is often transferred to others, and also a stimulus from the environment may divide upon entering the cerebrum, and be directed to several organs at once. In either case the result is the simultaneous excitement of several organs with the production of the new sensations arising from their interactions.

There are certain intellectual convictions which seem to be common to most people, whether they are actively conscious of them or not. We believe in the reality of our existence, and in the reality of the existence of those things outside of us that arouse sensation in us. We believe that changes do not happen without cause. We connect our past with our present experience, and believe in our personal identity extending through both. We believe in the stability of the universe, and the perpetuity of natural causes and effects. We believe we can do as we please. As these beliefs are common to all, they have been called *Intuitive*. Some of them at least are the results of unconscious reasoning processes, and from the uniform effects upon all brains, of the general forces of nature, they are common to men and brutes. We are mostly agreed, likewise, in the desirability of a knowledge of the True, the Beautiful and the Good. But on comparison, we find such knowledge is not axiomatic, since we disagree as to what constitutes it. I define *Truth* to be knowledge of things as they are, ideas of *Beauty* as the perceptions of harmonies which give us pleasure, and *Right* and *Goodness* as qualities which, in our estimation, might contribute to our interests. Even if we all agreed upon these definitions, however, our greatly diverse opportunities for observation would lead to various opin-

ions as to the things which are true, and our diverse inheritance of taste and habit of life must always make us differ in our ideas of the things that are beautiful, and of those which contribute to our interests.

The brain is a machine for reflecting the conditions of its environment. It is a machine built up by such of the forces in the environment as it reflects. We call the reflection of these forces reason. It follows that the original of reason is the interaction of the natural forces in the environment itself. These forces must be able to work out a reasonable result in the external world before a picture to be appreciated in consciousness as *reason* or reasoning, could be produced on the reasoning machine, namely the brain, or indeed before such a machine itself could be produced. A reasonable result in the operation of environing forces can mean nothing else than the necessary result of efficient causes. If no two things in nature ever did occupy towards each other the relationship of cause and effect for example, there never could have been an organ built up sensitive to the fact of such a relationship. Nothing exists in nature except through the operation of efficient cause, therefore everything in nature *reasonably* exists. Some authors have used the term *Supreme Reason* to indicate the original cause of things. There is indeed no generic difference between the efficient causes in the environment, by which one physical result will occur, only on condition that it has been preceded by a certain other one, and the efficient causes by which a certain state of brain tissue will exist, only on condition that a certain other state has immediately preceded it. To this chain of physical action in the cerebrum, we give the title of reason. Perhaps it is best to confine the title to this sort of action. Yet it is well to keep in mind that reason thus defined, is only a subdivision or specifically designated department of the great universe of cause and effect from which it is physically inseparable. The term *supreme* is not applicable to this department of nature, but neither is it applicable to any other; and if it be admissible to use it at all, it must be understood of the great aggregate of *Kinetic Energy* throughout the universe *including* cerebral action. For there is no warrant for an assumption that there is any original source of energy known to us, or that any one link in the chain of cause and effect that is accessible to us, or imaginable by us, is more original, more important, more necessary, or more dignified, than any other. Where every one is necessary the possible inferiority or superiority of any one is inconceivable. Since reason is the form of energy which follows and imitates other forms, and is in a certain sense a reflection of other forms, it follows that reason could not be a first cause of things. It would be as reasonable to say that the image in the looking-glass was the creator of the body that was reflected.

The organic world is full of examples of the adaptations of instru-

ments to the forces which work them. These adaptations are in some cases so striking as to appear purposive. Take, for example, the adjustments of the ear-drum, and other parts of the ear; the otoliths, the eustachian tube, the chromatic scale of the arches of corti, &c; the retina with its rods and cones, the lenses, the muscles for moving the ball, the pulley for altering the direction of the pull of the superior oblique muscle of the eye, &c.; the synovial lubricating arrangements for the joints, the sphincter muscles, the heart, the brain, the teeth,—in short, every part concerned in motion, or related to movement.

There is not the slightest doubt, that all these adjustments and arrangements are the result of the automatic action of various modes of energetic movement. Even their use is in some cases automatic, and often beyond the purposive control. That remarkable "pulley" muscle, the superior oblique, is an involuntary muscle, and its contractions wholly automatic.

In what does the difference consist between these natural contrivances, which have been built up through use without the intervention of a preconceived purpose, and those artificial contrivances, such as a beaver's dam, a spider's web, a bee's honey-comb, a birds' nest, a man's house or locomotive?

The natural contrivances are self-reproductive. Generation succeeds generation, repeating practically the same physical forms for ages. Even in the minutest details, they are usually liable only to extremely slow changes.

The products of these several parts, whether they be mechanical movements or sensations of some sort, likewise remain constant one generation after another, and they may be supposed to become changed only after some change has taken place in the machinery for their production.

Artificial works, although not self-reproductive, are also, nevertheless, produced in many cases without material change for a great many successive generations. Although no two bird's nests are precisely alike in details, yet for a thousand generations the nests of any particular species continue to be repeated after practically the same plan. The same is true of the beaver dam, the honey comb, the spider's web, and of ninety-nine out of every hundred of the contrivances of man. These artificial works, depending on the brain for their execution, remain as a constant production so long as the brain continues to be handed down without change from generation to generation.

We cannot fail to see the parallel here between what we call artificial productions and natural secretions. Tears, synovia, mucus, milk, urine, &c., are called secretions. They are articles of a foreign non-vital character produced by the action of certain organs called glands. They are

manufactured articles, made from other substances. A spider's web, a bird's nest, a beaver's dam, a Hottentot's hut, a locomotive, are called artificial works. They are articles of a foreign, non-vital character, produced by the action of certain organs called brain and muscles. They are manufactured articles made from other substances.

The action of the gland in the production of its secretions is automatic, but so is the action of the brain, and either of them is set going by the stimulation of a nerve current. It may be said that the activity of the gland results in chemical, and that of the brain in mechanical change. But there is good reason to believe that chemistry is only a branch of mechanics. Since then the same mechanical agency operates both the organs, and both are automatic; their products must sustain a common relationship to the rest of nature. They are equally natural; and we conclude that the so-called artificial work is a natural product, art is a subdivision of nature, and reason a mode of motion.

CHAPTER LXXVII.

ANIMAL INTELLIGENCE.

In studying the comparative anatomy of the brain, we found a wonderful correspondence running through the brains of all the vertebrates. This correspondence is the more striking if the attention be confined to a single class, as the mammalia for example. The correspondence of anatomical structure argues a correspondence of function. And judging from the general analogy of part with part, we are led to expect a similarity of function in each part compared with its analogue in the brains of different animals. The cerebrum having been ascertained to be the part whose reactions constitute the phenomena of intelligence, we have that much reason to conclude that intelligence may be looked for wherever there is a cerebrum. Allowance must be made, of course, for the size of the cerebrum, and it cannot be expected that reactions of as great number and variety can be obtained from a small as from a large cerebrum, other things equal. But one intelligence is precisely like another, as far as it goes. There is no difference between horse sense and man sense, up to the limit of the horse's capacity. I knew a horse once who knew enough to work a pump-handle up and down in order to get a drink of water. He got but a little at a time, because as soon as he saw a little water in the trough he stopped pumping and drank what there was, then pumped some more, and so on, showing his foresight to be qualitative, though not to a great extent quantitative. It is true he did not know anything about the internal construction of the pump, or why the water came when the handle went down. But he

knew the fact that it did come, and that furnished him a reason for pushing it down. Half the human beings who use pumps, reason no further on the subject than that; and even when they do, their reasoning, pushed as far as possible, ends at a barrier where the only solution attainable is, "this thing is so, just because it is." In other words, my senses tell me it is so, but they do not show any antecedent cause for it. For example, we may trace the origin of energy to the attraction of gravitation, but all we can tell about gravitation is that it exists. We utterly fail to see any cause behind it. The only difference between the reasoning of the horse and that of the man, is that the former sooner reaches the limit beyond which his senses disclose no further relationship of cause to the visible effect. His intelligence compared with that of man, is simply as a less quantity compared with a greater.

It has long been customary to attribute all the actions of the lower animals to instinct. If by instinct we mean a powerful tendency to do a thing according to a hereditary habit in the face of a strong and obvious stimulation toward a variation from the habit; and if by intelligence we mean a disposition that allows extraordinary or unusual stimulations to modify, influence or control the actions, then we must concede that the actions of all animals, including men, are in part instinctive, and in part intelligent. There are extremely few actions which it is within the bounds of possibility to perform twice exactly alike. Considered in detail, no two bird's nests are precisely alike. The weaving together of the straws, sticks, leaves, feathers, hairs, rags, papers, and what not, that go to compose the nest, is in no two alike; and they necessarily vary in the detail of attachment to the crotch of the tree, or other locality in which they are placed. The general principle of a secure receptacle for the eggs, in shape to prevent them rolling out, and in thickness to retain warmth, runs through all, just as a man's house generally includes walls and a roof; but in material and other detail there is great latitude. In some cases, even where long experience and habit have established a uniform method, we find examples of variation when the circumstances appear to demand it, in the case of other animals as well as ourselves. For example, "our common cliff swallow, known also as the cave swallow and the 'Republican,' formerly built against the face of a cliff, and, as a protection against the weather, the nest, instead of being open at the top, was bottle-shaped, the entrance being through a kind of neck at the side. Now that the country has become populous, however, this swallow has taken to nesting under the eaves of barns, where it is shielded from the rain by the overhanging roof. Little by little, therefore, the wise bird has given up its more elaborate method of construction, till now you may see, side by side, nests that are simple mud saucers, nests that are built in the old-fash-

ioned bottle method, and nests half way between the two extremes, showing plainly that a process of adaptation is going on. A Pennsylvania newspaper lately reported a clever piece of work by a pair of these same cave swallows. They had built a nest in the old style under the eaves of a barn, and when it was done, an English sparrow took possession. The swallows made frantic efforts to dislodge the intruder, but could not drive her out. Then they went deliberately to work and plastered up the neck of the bottle with mud, burying the sparrow alive, after which they built another nest close by, and occupied it as if nothing had happened." (Youths' Companion, Dec. 27, 1888.)

A story, something like the above, is related in *Ballou's Monthly*, as follows:

"'The 'Cow-Bunting,' of New England, never builds a nest. The female lays her eggs in the nests of those birds whose young feed, like her own, on insects and worms, taking care to deposit but one egg in a nest. A cow-bunting deposited an egg in the nest of a sparrow, in which was one egg of the latter. On the sparrow's return what was to be done? She could not get out the egg which belonged to another, neither did she wish to desert her nest, so nicely prepared for her own young. What did she do? After consultation with her husband, they fixed on their mode of precedure. They built a bridge of straw and hair directly over the two eggs, making a sort of second story in the house, thus leaving the two eggs below, out of the reach of the warmth of her body. In the upper apartment she laid four eggs and reared her four children. In the Museum at Salem, Massachusetts, may be seen this nest, with two eggs imprisoned below."

Romanes, from whose work on Animal Intelligence I shall liberally quote, recites many cases of adaptation of instincts to new conditions by the use of intelligence, especially in cases of bees, in changing the shape of their cells, and the direction of the combs; building from below, or from one side, propping up and securing falling comb, &c. Certain humble bees, when prevented from gathering moss to cover their nests, tore up a piece of cloth, carded it with their feet into a mass which they used as moss. Some bees used grafting wax off trees, instead of their own propolis; also oatmeal. Other bees, which naturally tunnel into hard banks to make their cells for the deposit of eggs, will at times avail themselves of holes ready made, as a straw in a thatched roof, a shell, &c., which they will partition off to suit. Such intelligent variations of instinct might, if practiced long enough in their turn, become instinctive.

A spider lost all its legs but one, and was compelled to adopt the habit of catching its prey by "stalking," because it could not build its web. Afterwards its legs grew out, and it built webs again.

Birds modify their nests to suit circumstances, taking those of men's make, as wrens, one kind of owl, one Bluebird, the Pewit, Flycatcher,

and House Sparrow. "All our Swallows have been modified by human agency excepting the Bank swallow." The Paradise Duck of New Zealand, when its nest on the ground was disturbed, built a new one in a tree, and carried its young down to the water on its back. Similar conduct was observed in the wild ducks of Guiana.

Palm Swifts, of Jamaica, always till 1857, built their nests in palm trees. Then two palms containing the nests of a colony blew down, and then the swifts drove the swallows out of the assembly house and built there, where they remained thereafter. Their nests were there less elaborate, because less exposed than in the trees.

A hen which had reared three broods of ducks, was in the habit of flying out to a stone in the water and have her brood swimming around her. Afterwards when she hatched a brood of chickens she flew out to the stone and called her chicks as she had done the ducks. Another hen which had raised ducks, when she afterwards had chicks, tried to teach them to swim and pushed them off into the water for that purpose. Another hen hatched a peacock, having to set a week longer than usual for that purpose. Afterwards she took care of him, combed his head, &c., she standing on a seat and he bending his head with satisfaction, for 18 months, never laying any eggs during that time.

A cat deprived of three of her five kittens, took as many young rats, and afterwards losing the other two kits, took two more rats, suckled them and took care of them, they reciprocating. A cat reared a leveret, another reared a puppy.

These are cases of intelligent adaptation.

Humble bees and common bees visited a patch of kidney beans; the latter at first sucked the flower, but the former bored with their mandibles small holes through the under side of the calyx, and so got at the nectar more directly. The other bees soon caught on to this and sucked at these holes, too, though they did not bore for themselves. The above actions include observation and imitation.

Dogs learn by experience how to fight strange animals, as for example, a Badger. Dogs learned from each other in the Falkland islands how to attack wild cattle.

Many birds learn the tunes of others. (One was taught the Marseilles.) Mocking birds, Parrots, Jays, Jackdaws and Starlings, all imitate, especially when obliged by confinement to hear particular tunes. Those that are quick at attaining, also quickly forget, being like mankind in that as well as other respects.

Puppies reared with kittens often imitate their way, leaping at prey, washing their face, &c.

Strange cattle and young lambs without their mothers are poisoned by plants, which are avoided by those experienced. So they learn poisons

partly by experience. Imitation is stronger among the more intelligent animals, monkeys, children, feeble minded people, &c.; the most intelligent, however, using more original reason. Learning to speak is chiefly imitation. Actions which are in part instinctive, are purposely educated in their young by old animals. Young hawks are practiced in swooping down on prey by the old ones dropping dead mice and sparrows for them to catch, which at first they generally miss. Old birds generally help to teach the young to fly by imitation, though it is also instinctive.

An Eagle hatched out two goose eggs; one gosling died, and the other it raised, feeding it on flesh, contrary to its nature, and which it at first refused. To run, jump, chirp, scratch, and cuddle together (as if under a hen), are instinctive to a chick four hours old; but chicks do not know how to drink till taught by imitating older ones.

There are artificial and acquired instincts. The cat and dog have been made tame by artificial culture and selection. "Where there is no opportunity for the exercise of pure instinct, it will languish like all the natural senses." Wild foxes, jackals, wolves, &c., and the cat tribes, taken and tamed, are never broken of their desire to attack sheep, poultry, &c., and young dogs have to be taught also, but when grown, the civilized dogs do not interfere with domestic animals, a case of diverted or modified instinct. But cats are not so well educated about birds (pigeons and canaries), so their old instinct crops out against them while it discriminates in favor of fowls. In some places, as in the Polynesian Islands, dogs from being carnivorous have become strictly vegetarians. In changing the instincts of dogs, only those affecting men's interests have been modified. Others they still hold, such as covering excrement, rolling in filth, turning round and round to make a bed, hiding food, &c. "Most carnivorous animals in their wild state have an idea of property as belonging to captors." From this the dog's idea of his master's property, and himself as part of that property, has been developed. A dog went along with a donkey with apples in baskets on his back and prevented the donkey from reaching around and getting them as he tried to do.

Ourangs and other ape tribes are polygamous, the males contesting for the headship of the family, the young and strong driving off the old ones, who thereupon betake themselves to a solitary and misanthropic style of life. Each one will appropriate a certain district for himself and not allow any one else to trespass. Other animals have their holes and dens, and birds their nests, which they defend against aggressors. Remarkable, too, is the cultivation of an instinct of faithfulness by selection, together with love of approbation. It was an interesting case, that of the Scotch "Collie" or shepherd's bitch, that was delayed in bringing home her sheep by having to give birth to a litter, but brought

the sheep in (late) all right, and one pup in her mouth, and went back after her other puppies one at a time, the last one dead. Instincts cross by crossing breeds (same in human beings).

The dung beetle in sheep districts uses sheep pellets, for the deposit of its eggs instead of making them itself; an adaptation to local circumstances. Certain ants in a part of Siam, subject to inundation, make their nests in trees. There are cases of bees becoming carnivorous. Wasps are naturally carnivorous.

The ring plover in Norfolk and Suffolk formerly were shore birds, but the sea having receded several miles, the birds have remained where they were, and changed their habits to correspond. Cattle in Africa and United States have been known to suck bones, from which a carnivorous habit might possibly arise. Probably the Pig has so become partly carnivorous. The Bear has changed from being carnivorous to become in part a vegetarian.

In Ohinitahi the mountain Parrot has partly changed from a honey eater to a flesh eater. They will attack a sheep and pick a hole in him, and suck his blood. If he lies on the injured part, they will tear open another hole, and often he dies.

There are Rabbits on the Island of Sor that do not burrow. Hyenas in the uninhabited parts of South Africa do not burrow, but do in the inhabited parts. "Several mammals and birds usually inhabit burrows made by other species, but when such do not exist, they excavate their own habitations." Beavers of Europe and Oregon go single, and do not associate in colonies, or build dams, or huts. Wild canines do not bark, but growl. European dogs, when conveyed to Guinea, in a few generations cease to bark, and go back to the growl of the native dogs. Certain cuckoos deposit their eggs in the nests of other birds, chiefly magpies and crows. Some also colonize and build big basket-like nests for the whole flock.

Observe the educated instincts of the Shepherd dog, the retriever, and the silent pointer, a sub-breed of the noisy hound. A young pointer will imitate other pointers when he does not see the game himself. Some point without teaching, but most require a lesson or example to imitate. It is instinctive, because the young dog cannot be supposed to know why he points. "The habits and propensities of the springing spaniel would never have been acquired but for the art of shooting birds on the wing."

Many birds with well-webbed feet seldom or never go near the water, as the Upland Goose, of South America, certain Ducks, Sandwich Island Goose, &c. Other good water birds have only partial webs or only a slight fringe of web around each toe; as the Water-hen, the Grebe (thoroughly aquatic), and others of the Crex and Passa genera

that swim well and are always about the water. Yet the Cornerake of one of these genera is not at all aquatic, though possessing the fringed toes.

These cases show the adoption of new habits which have not been practiced long enough to entirely modify the anatomical structure built up by their former habits.

The foregoing examples showing the gradual modifications of instincts under the stimulation of changed environment, at the same time clearly point out the ultimate identity of the origin of instinct and intelligence. Actions, when they are modified by casual and unaccustomed stimulations, we call intelligent. But if such new stimulations continue to exert their influence regularly, the actions follow as uniformly, and we then call them instinctive. Memory, the basis of intelligence, is found to be exercised by animals of the simplest structure.

In children, power of memory and association is shown early. In the ninth week B's baby associated the bib with the bottle and stopped crying when the bib was put on, and at the tenth week put the bottle to her mouth herself. At eight months Pryer's baby associated all bottles together.

A limpet (gasteropod) knows its home and goes back to it. A razor-fish avoided a place where it had been alarmed. A snail, the Helix pomatia, leaving a sick mate crawled over a garden wall, and next day crawled back again. But the highest memory of a mollusk is in the cephalopod Octopus, one of which remembered an encounter with a Lobster. They also learn to know their keeper. But the Echinodermata and the Hermit crab could learn nothing by association. But a lobster "mounted guard upon a heap of shingle, beneath which it had previously hidden some food." Ants and bees remember for months places where they got honey or sugar. They will also return to nests and hives they deserted the year before. Sir John Lubbock taught some bees to know the difference between an open and closed window. Observations were made by Messrs. Bates and Belt, of "sand wasps carefully teaching themselves (by taking mental notes of landmarks) the localities to which they intend to return, in order to secure the prey which they have temporarily concealed." Beetles, earwigs, and house-flies also have memories. Fish remember their spawning place from year to year; they learn to avoid baits; they remove young from a nest which has been disturbed, and they have associated the sound of a bell with the arrival of food. "Batrachians and reptiles are able to remember localities and also to identify persons." Turtles also migrate to a shore annually to deposit eggs. Birds remember nests and persons from year to year. Some acquire words and phrases, and upon forgetting, have made efforts to recollect; a memory in all respects the same as humam. A horse remembered a road

and stable eight years after; a dog, the sound of his master's voice five years after, and the sound of a clinking collar three years after. An elephant remembered his keeper after running wild for fifteen years.

The faculty of memory of necessity produces imagination, and there is plenty of evidence of its possession by the lower animals. It is shown in the wariness of animals, their apprehension of danger involving imagination. It is shown in the cunning and stratagems of animals, as in birds feigning lameness to invite pursuit; and in foxes obliterating their tracks by wading in a stream, and by doubling on their tracks, &c. Romanes mentions the case of a crab that took out a shell that had fallen into its hole, then seeing three others near the mouth of the hole ready to fall in, moved them off out of such risk.

Imagination is shown in dreaming, and it is known that elephants, horses, dogs, and Canary birds, Eagles, Parrots, &c., dream. A Parrot is mentioned that talked in its sleep, and a watch-dog that was a somnambulist. Like men, the lower animals are liable to affections of the brain which cause delusions. In hydrophobia they see phantoms, and on various occasions dogs have been known to be the victims of illusions shown by the gazing at vacancy, snapping and growling. An ape is mentioned that had a sun-stroke, in consequence of which it became subject to delusions.

Many animals become strongly attached to persons and places, so that when away they suffer in mind. Occasionally we hear of a dog dying of grief, upon the loss of its master. A dog is mentioned that refused to eat after his mistress went away. Many horses are much more free to go, when returning towards home than when driven away. They are impelled by the imagination of home comforts. Many animals return home from long distances. Pigs, cats, dogs, pigeons, &c., do this, and even snakes, toads, and frogs. A tame snake, taken in a close carriage from Madras to Pondicherry, over 100 miles, found its way back. They show in this, not only memory of the home, but a wonderful faculty of direction.

Some animals, dogs, in particular, appear to be superstitious. That is, they act at times as if they fancied an inanimate object to be a person with life and will. Thus, a dog playing with a stick, accidently hurt himself with it, when he dropped it in great alarm and ran off, as if he thought the stick actuated against him by maglignant motives. Another dog barked at a parasol moved by the wind, and another was astonished and alarmed at seeing a dry bone it had been playing with drawn off by a fine thread, and ran away. Another dog was alarmed by the behavior of a soap-bubble, and scared out of the room when it finally burst. Another that heard thunder for the first time when 18 months old, was badly scared, and equally so when he heard artillery practice at

at a distance, thinking it the same. He would always run home when he heard it, and never got over it. He was affected the same way by apples being rolled upon a floor in the apple room, but got over that when *shown the cause.* I know an intelligent dog who is in the habit of visiting a neighbor's premises every day and is familiar with the place. One day last winter coming over as usual, he suddenly spied a large snow-ball that had been rolled up, and left in the yard. He was startled by the unusual object, and sprang back several paces. Then he barked at it several times, without provoking any hostile demonstrations from the ball, and so ventured a little closer and barked again, and so on till finally, being satisfied of its harmlessness, he went up to it and made its acquaintance, dog-fashion.

In Uruguay, dogs are trained to take care of the sheep in the following way: The pup is separated from its mother when very young, and made to suck an ewe three or four times a day, and a nest of wool is made for it in the sheep-pen. At no time is it allowed to associate with other dogs, or with children of the family; moreover, it is generally castrated. Brought up thus, it learns to consider the flock as its family. It stays with it and defends it just as it would the master's house if it were brought up there. When it is away from the flock it is cowardly, like any dog away from home; but if pursued by other dogs, when it reaches the flock it turns around and defies any number of them, and they respect his rights here as one on his own ground and supported by his family, for the sheep look to him for protection, and close up in his rear as they would to the leading ram. . The shepherd dog comes to the house daily for meat, and skulks back again as soon as he gets it, often pursued by the house dogs. They are easily taught to bring in the sheep to the pen at night, and to take them out in the morning. (Darwin, Cruise of the Beagle.)

There are several species of crabs, called Hermit crabs, which take possession of the shells of mollusks, get into them and crawl off with them on their backs. Certain species of the crabs always use certain species of shells. In some cases the large claws, or pincers, are well adapted, when drawn back, to form an operculum or lid to the shell, answering much the same purpose as the operculum of the original owner. One of these species of crabs, allied to or identical with the Birgos latro, on the Keeling Islands, grows to a monstrous size, and is remarkable as a cocoa-nut eater. He begins on a cocoa-nut "by tearing the husk fibre by fibre, and always from that end under which the three eye-holes are situated; when this is completed, the crab commences hammering with its heavy claws on one of the eye-holes till an opening is made. Then, turning round its body, by the aid of its posterior and narrow pair of pincers, it extracts the white, albuminous sub-

stance." "These crabs inhabit deep burrows which they hollow out beneath the roots of trees, and where they accumulate surprising quantities of the picked fibres of the cocoa-nut husk, on which they rest as on a bed. The Malays sometimes take advantage of this, and collect the fibrous mass to use as junk." (Darwin, Cruise of the Beagle, 492.)

The species of these crabs called the Purse crab, is found on the Caroline Islands. It grows to from 18 to 24 inches long, and can raise itself to a hight of nearly a foot above ground. It climbs the cocoa-nut tree, cuts off two or three nuts with its strong claws, and throws them down. It pulls off the husks, and breaks open the nut like the crab described above. But sometimes it breaks the nut by seizing it with its big pincers and striking it against a stone.

The skill and versatility of the Beaver are of a high order. The construction of their works is adapted to the locality, and some of them are very extensive, requiring the co-operation of many workmen for a long time. The liability of their dams to accident from floods, requires their knowledge of hydraulics to be adaptive, as no two cases are precisely alike. Their skill in working out the details of a dam, are often entirely human. They will cut down a tree a foot in diameter, cutting in such a way as to cause it to fall across the stream. Then they will cut enough stout sticks to make a slanting floor when laid side by side, reaching from one side of the stream to the other, one end of each stick resting on the large cross-log. Then they will cover the slanting floor with grass, leaves and earth to make it water-tight. If a break occurs they do not lose their heads but know just how to stop it up.

The ape tribes are, next to man, the most intelligent. They possess a great faculty for imitation, and a desire to do what they see other folks do. Imitation is an exceedingly human faculty, the greater part of our actions and ideas being copied by the rising generation from the retiring one. But the ape is also liable to those new original ideas which arise by the breaking up and reconstruction of old ones in the cerebrum. An orang is mentioned that learned how to open his cage door by turning the key or latch. He reached it by means of a suspended rope to which he clung. His keeper tied knots in the rope so as to make it too short for his purpose, and then he climbed the rope above the knots and untied them. When presented with a bunch of keys, he tried them one after another to unlock the door he wanted to open.

The following anecdotes prove the possession, by different animals, of such reasoning powers as are competent to work out purposive actions, just as they are worked out in a human brain.

Wm. Livesay, in Jefferson Co., Ill., many years ago was much troubled by crows, which as soon as his corn was up, swarmed down into his clearing, and guided by the tender spears just visible above the

ground, dug up and devoured hill after hill of the sprouting grains. One day, gun in hand, he cautiously approached the field to get a shot at one he spied diligently at work pulling up his corn. Another crow sat upon a tree evidently as a sentinel, for he at once began to warn the other of his danger by earnest caws. But the other was too much absorbed in his work to heed the warning, and dug away industriously, while the sentinel redoubled the vigor and anxiety of his cawing. Finally, just as Mr. L. was about taking aim at the offending bird, the sentinel darted down upon his heedless friend, and giving him a sharp prod with his beak, they both flew off and made their escape. St. George Mivart, in his "Origin of Human Reason," declares that animals do not make signs, "for a sign is a token or device addressed to eye or ear, depicting by an external manifestation, some newly arising combination of ideas." In the light of this definition I hold the foregoing crow made signs. We shall have other examples. Lubbock mentions the case of a crow which was able to count four. The owner of a field in which she was accustomed to commit her depredations, was anxious to shoot her, and to deceive her, two men were sent to the watch house, one of whom remained, while the other went away; but she appeared to know that one from two leaves one, and so she kept at a safe distance. Next day three men went, and two came away, but still her arithmetic told her one was still there, and it was only after at least five had gone that the *sum* got too big for her to manage, and she was induced to venture within range. The crow, however, is not always good in arithmetic. A Connecticut farmer, Mr. Brown, was greatly troubled by crows digging up his corn. He built a rail pen in the field and concealed himself therein with a shot gun ready to shoot the intruders as soon as they came. But the cunning birds knew he was there, and he waited for some hours in vain for them to come within range. No sooner had he left, however, than down they swarmed again. Mr. Brown then went to the pen again accompanied by his hired man. In a short time the latter went back to the house, and the birds now thinking the coast was clear, sailed down into range of Mr. Brown's gun which quickly got away with ten of them. "Ah," chuckled he, "ye are cunnin' critters but ye can't count wuth a cent." (Youths' Companion, Oct. '88).

A crowd is often liable to be misled by the incompetent. The above disaster might have been due to the heedless impulsiveness of untaught youngsters. If they had been influenced by an educated old head like that told of by Lubbock, the calamity would have been averted.

Charitable Blue Jays. A gentleman in Wisconsin, one day last July or August, observed jay-birds carrying food, and could not for some time imagine what they did with it as it was past the time for feeding

the young. Somewhat later he was pleased to discover that they were feeding and otherwise caring for an old and partly blind and helpless companion. He caught and examined the old bird, whose feathers were faded, his claws much worn, his bill dulled, the wings and tail ragged. After his liberation he flew back to his companions who were waiting near by in sympathetic interest. During the next eight days he observed them feed him, attend him and warn him of danger, directing by their voices which way to fly. They guided him regularly to a spring not far off, where he daily took a bath with some of his companions always standing guard. (Youths' Companion, Dec. 6, 1888.)

Bird Courts of Justice.[1] A tourist in the Alps saw a flock of 60 or 70 ravens occupying a circle, in the middle of which was one which appeared to be on trial. There was much clatter of tongues and wings by the surrounding crowd, but they paused occasionally in order to permit the accused to reply, which he did most vociferously with intense energy, but all his expostulations were speedily drowned in a chorus of dissent. At last the verdict seemed to be reached, and was instantly executed by the whole flock pouncing upon the unlucky culprit and tearing him to pieces.

Two cases are given of the punishment of female storks for supposed marital infidelity. One case occurred at Smyrna. A French surgeon stole all the eggs from a stork's nest and replaced them with hens' eggs. After they were hatched, the male stork suddenly disappeared, returning after two or three days accompanied by a large number of others. They assembled in a circle, the supposed delinquent female in the midst. After some discussion the whole flock attacked her and tore her to pieces. The other case happened near Berlin. The stork's nest was in a chimney of a mansion. The owner took out the solitary egg and replaced it with a goose egg. The stork did not notice the change, and hatched the egg. Then the male bird rose from the nest, flew around several times with wild screams. He disappeared, returning in four days with about 500 storks. They held a parley, one bird about 20 yards away apparently haranguing the rest. All this time the female had remained in her nest, but in evident fear. The discussion continued several hours, several different birds addressing the meeting. At last they broke up, and all flew toward the nest. The leader, probably her husband, knocked her out of the nest, and the rest destroyed her. the gosling and the nest.

A correspondent of the London Spectator relates two anecdotes of ducks, illustrating sagacity and sympathy, or, as he calls it, courtesy. He had, among 50 or 60 fowls and ducks, a solitary little old bantam hen, which became blind, and was so persecuted by its mates that it

[1] Popular Science Monthly, Oct., '88.

took refuge in an obscure place where it had nothing to eat, and would have starved but for a tender-hearted duck who twice every day carried and deposited before the hen as many grains of barley—some 20 or 30—as her beak would hold. The duck performed this humane office for about three weeks until the hen died. The other story is of five ducks which were constantly bullied and driven away from the common feeding place by an arrogant and domineering rooster. At last, on one occasion having been driven into a corner, they there held a consultation and entered into a conspiracy; after which, returning they surrounded the rooster, and making a concerted attack "fairly hustled him clean out of the yard. To see the surprise of the cock as he jumped from side to side to avoid the pressure of the attacking party, was ludicrous in the extreme. The victory was complete; from that hour the ducks were never again molested." (Popular Science Monthly, Oct., 1884.)

Birds are fond of music and color. Some adorn their nests and select their companions, foods, fruit, &c., with reference to the color sense. The sparrow enjoys the music of other birds. They have been known to gather about a robin when he was singing. Mr. Fish says: "A friend sends me an account of a Bobolink that, placed in a cage with some canaries, exhibited great delight at their songs. He did not sing himself, but with a peculiar cluck could always set the canaries singing. After a while he began to learn their song, note by note, and in the course of a few weeks mastered the entire song." The goose is also fond of music, an air on a fiddle will set a whole flock wild with delight. He relates a story of a gander that was set to dancing a lively jig by an air played on an accordeon, the gander keeping good time with the music. "For several minutes he kept up the performance, to the great delight of the company. The experiment was tried several times for a week or more, and the tones of the accordeon never failed to set the old gander into a lively dance." (Pop. Sci. Mo., Sept. 1884.)

The fellowing story of a Dancing Goose is from the Macon Telegraph:

"For several weeks the employes of the gas works, as well as the electric light works in the same neighborhood, have been seen to stop every evening on quitting work and surround a lot of little colored children who daily congregate on the square near the railroad embankment. Monday a Telegraph man determined to see the cause of the gathering, and on proceeding to the locality found the little colored children engaged in 'patting,' with all their might, an old gray goose in the center of the circle dancing, first on one foot and then on the other. The gander seemed to enjoy the dance, and, though it may read like a 'fake' was keeping most excellent time to the rude music of the children. For an hour or so the goose will dance to the patting, always stopping when the children cease their music and seems always ready to resume."

The keeper of a Scottish estate, who was one day strolling about the fields with a gun, saw a Kestral, or Hawk, flying towards him against

the wind by a slow, labored and tortuous flight, as if it had been wounded, or was struggling with an unwieldy burden. After a little the bird lit on a boulder, and was earnestly engaged for five minutes at some occupation the man could not then make out. He then resumed his flight, this time much more steadily and directly, and when he came within range of the spot where the keeper was concealed, he brought him down, and with him a plump partridge which he was carrying, and which was nearly destitute of feathers. Going back to the rock, the keeper found all the missing feathers belonging to the partridge, and it now became apparent that the hawk, impeded in its flight by the action of the wind on the limp and pendent feathers of the partridge, deliberately stopped on the rock and pulled them out.

A curious incident that occurred recently on one of the bridges crossing the river Limmat, which flows through the city of Zurich, illustrates the sagacity of the gulls, or terns, which frequent the Swiss lakes. A gentleman was in the habit of feeding the birds with the refuse of meat of which they are very fond; and one day as they clustered eagerly about his head, his hat was accidently knocked off, and fell into the river. The lookers-on laughed at the mishap, and a boat was about pulling off into the stream to secure the lost article, when, to the surprise of every one, a gull was observed to dart down upon the floating hat. After several ineffectual attempts, it succeeded in rising with the hat in its beak. It flew straight toward the bridge, and dropped the well-soaked hat at its owner's feet amid the enthusiastic applause of the bystanders. "Those who believe that animals have the faculty of reasoning, will find their faith strengthened by this anecdote. Instinct could never have led a gull to retrieve a benefactor's lost hat." (Youths' Companion, Nov. 28, 1889.)

A Boston naturalist and his son Walter, eleven years old, were fishing at Lake Quinsigamond. Having caught some fish they put them in an open basket, and placed the basket in the edge of the water, with its rim about four inches above the surface of the water to prevent them jumping out. But when the boy went back to see the fish next morning they were found to have all jumped out. He then proceeded to catch another lot, and moved the basket to a hole he made in the sand some distance from the water. The water in the sand filled the basket, and in it he put his fish and waited near by so he could observe results. "By and by," says he, "I saw one of the fish flop out of the basket and land on the sand. By and by another one flopped out. After awhile they had all jumped out and were floundering around on the sand. I let each one stay there in the sun quite awhile but not long enough to suffocate, and then when all were pretty thoroughly punished, I put them one by one back into the basket. After every one had jumped out I

was curious to see whether they would jump a second time. Two of them did leap out again, and I let those stay out on the hot sand a little longer than I did the first time. Then I put them back into the basket. No more tried to jump out and I was sure that they had learned their lesson. So I took the basket and pulled it along through the water to the same place where we had it before, and sunk it there." The following morning he visited his basket and found his fish all there. "He had, it was plain, succeeded in conveying it to the intelligence of these fishes, by an experience very unpleasant to them, that they had better not leap out of the basket. As this story is a true one, it seems to prove that the fishes have a considerable degree of intelligence."

A Reasoning Lobster. This story is told in the Bulletin of the U. S. Fish Commission. "The sagacious Crustacean's home was under a rock in Buzzards Bay, in water about five feet deep. The author carefully adjusted a noose over the hole, and baited it with a piece of Menhaden. The lobster passed its claw through the noose to get the bait, and the noose was drawn upon the claw, but slipped off when the animal had been pulled half out of his hole and he escaped. The noose was fixed again, but this time, instead of putting out his claws as before, the lobster first put his feelers through the noose, felt the string all the way around, and then pushed one claw under the string and seized the bait. The experiment was repeated several times, but every new setting of the trap was met in the same deliberate way, as if by one who had thought the matter out."

There is plenty of evidence that animals have some way of making themselves understood by their associates. An example in point is furnished by an English paper, of a couple of thirsty cows which presented themselves at a cottage gate, showing by their uneasiness that they wanted something. Although strangers, they were supplied with water and went off. In half an hour they came back with three others who were likewise thirsty, and when they were likewise supplied, the whole five went off with evident tokens of satisfaction.

A Tale of Two Dogs. A gentleman, accompanied by two fine specimens of the water spaniel, went down to the landing of the Newport ferry at the foot of Lawrence street. Somehow, he became separated from the canines, or rather they failed to follow him aboard. The boat had got out into the stream, when the dogs caught sight of their master and discovered he was fast leaving them; standing on the edge of the float, both set up a vigorous yelping which attracted the attention of the bystanders. Suddenly, the older and larger dog plunged into the river and began to swim rapidly toward the Kentucky shore. He had gone about 100 yards when he seemed to became aware that his brute companion had not followed. Turning round, he swam back toward the

spot where the younger dog stood. As he drew alongside the float, he made no effort to get aboard. The two began to bark at each other, to hold an animated conversation in the dog tongue, as it were. The older dog, as he floated by the side of the landing, barked encouragement to the more timid animal, and apparently was urging the latter to jump into the water. This barking duet lasted some minutes, and the young dog seemingly convinced by his companion's assurance, grew bold, and suddenly bounded into the river. The first dog gave a delighted yelp, and both turning their noses toward Kentucky, began to swim straight across, side by side. Both continued to bark until they reached the shore, and could be heard on both sides of the river. The people on the ferry on the Kentucky shore saw the strange race, and, with the people on this side and on the bridge, watched it to the end. The dogs landed opposite the barracks where they were awaited by their owner who, with several other gentlemen, had hurridly walked down the bank. There was no limit to the delight of the two animals as they rushed up to their master. The river at that point is nearly half a mile wide. The action of the dogs seemed to indicate that they had a language of their own, and the paternal manifestations of the older brute were most interesting to see." (Cincinnati Enquirer, Oct., '89.)

The people of Assam tell the following stories of the wild dogs of that country which hunt in packs. When a pack goes out to hunt, an old dog goes in front and searches for fresh scent of a deer, and ascertains approximately the locality of the game. He then returns to the pack, and disposes it around the game in a circle a mile in diameter. He then goes in and drives the deer out toward the circumference of the ring. It is here intercepted by the other dogs, and so driven from side to side of the ring which is constantly contracted until the deer is surprised and baffled in all directions, and finally exhausted and captured by his wily antagonists, whose combined wit is thus more than a match for the superior activities of the deer.

The Virginia (Nevada) Chronicle is responsible for the following story of coyotes, the name given the small prairie wolves common in all our new states in the west:

"Residents in the vicinity of the Philadelphia brewery have been robbed of over 500 chickens in the past few weeks, and until recently were unable to ascertain the identity of the thieves. A watch was set and it was discovered that they were coyotes. The full-grown animals could not get into the chicken-houses, but detailed their cubs to crawl in through the holes left for chickens to enter. Once inside, the cubs killed the chickens and pushed them through the holes to the full grown coyotes waiting on the outside, who bore them away to their rendezvous in the adjacent hills and ravines in that vicinity, which are swarming with these animals, and at night the air is vocal with their howls, the treble cries of the cubs forming a strange accompaniment to the deep bass of the older contingent."

An interesting story is related by the London Globe of a dog near Manchester whose wealthy and indulgent master gave him a penny every day with which he went to a bake shop and bought a biscuit for his lunch. At one period the dog all at once became impatient for lunch time to come around, and by evident signs begged for his penny before it was due. It afterwards came out that on these occasions instead of going to the baker's, he went to a tripe seller's, where he bought and paid for a "tempting skewering of paunch." This he took to an empty house in the neighborhood, in the cellar of which a sick and wretched stranger dog had crawled for shelter. To this poor tyke, the benevolent dog gave his meat every day for a week or more. Why did he not take him his biscuit, instead of transferring his custom to the tripe man? Did he ascertain that meat hit the stranger's case better? If so, how?

The following is told by an English paper. "An elephant attached to Womwell's menagerie, was treated in Gloucestershire by a druggist for internal spasm. The animal recovered, and duly departed from the town. This was in 1870. But in 1879, when the druggist stood at his shop door to watch the menagerie again enter the town, the elephant crossed the street, advanced to the man of drugs, placed his trunk on his hand, and grunted agreeably to show her remembrance of past kindness. At night, on visiting the menagerie, the elephant drew the druggist's attention to her side, to which a blister had been applied nine years before. In 1881, the elephant again entered the town. Recognizing her chemist friend in the audience, she lifted him gently off his feet by means of her trunk, and drew his attention to one of her forelegs. The keeper explained that the limb had been lanced by a veterinary surgeon, and that apparently she was comparing notes of the difference between the gentle blister of her friend, and the procedure of the surgeon. It is not often that services are so long and gratefully remembered either by quadrupeds or by 'the paragon of animals' himself."

Cat Sagacity. A gentleman living near Allegan, Michigan, relates an interesting story of feline sagacity. Some person owning a cat and three kittens, and desiring to be rid of them, took them in a bag to a wood near the gentleman's house, and dropped them. In a short time the mother cat was seen to approach the house with a kitten in her mouth. Reaching the door, she dropped the kitten, and returned to the woods from whence she soon returned with another kitten, but instead of leaving it where the first was left, she took it to a neighboring house, then, returning to the woods brought out the third, and last kitten, and left it at still another neighbor's. The old cat then disappeared, and was not seen again until it was time for the kittens to be fed, when she visited each house, nursed the kittens, and then disappeared again. This course of procedure she followed until the kittens were weaned, when

she disappeared, and has not been seen since. Was it reason, or instinct that caused the mother cat to distribute the kittens to different homes, so that all might be adopted and the lives of all spared? (Youths' Companion, Oct. '89.)

The observation of the ways of animals leads to the conclusion that they exhibit the following mental qualities: "Surprise, fear, sexual and parental affection, social feelings, pugnacity, industry, curiosity, jealousy, anger, playfulness, affection, sympathy, emulation, pride, resentment, esthetic love of ornament, terror, grief, hate, cruelty, benevolence, revenge, rage, shame, remorse, deceit," cunning, sense of the ludicrous, ideas of duty and loyalty to a trust, and probably superstition.

CHAPTER LXXVIII.

INSTINCT.

All organic action being reflex or automatic, the rapidity of the response to a stimulation, depends upon the perfection of the adaptation of the machine to its stimulating force. Practice and habit constitute the education of the organic machine and develop it; that is, cause it to work more readily and easily, and with less expenditure of energy, and less friction. If two men see the same object, as a work of art, or a machine, or a book, one will get from it a great many more ideas than the other; that is to say, more cerebral organs will be excited or constructed in his case. For this reason, then, simply that his brain is the more easily get going, we call him the smarter man. If a person is set to work upon a task which is to be repeated a great number of times, such as the manufacture of a particular article, the first one he makes will require a long time and be botched and clumsy. But after making a great many, the time required will be much less, and the product much neater and more workmanlike. Moreover the effect on the workman himself will become different. At first he has to give the work the closest *attention*; every detail is watched and he must concentrate all his mind upon it, and not think of anything else. But after awhile it becomes so easy that it is performed with very slight attention, the eyes need not be fixed constantly upon the work, and the thoughts may sometimes wander off to other things. Now, as we have seen, the degree to which the attention is enlisted is an index of the amount of blood consumed in the action, and of the vividness of consciousness, if any be aroused by it, and therefore of the amount of energy consumed in the work. The constant tendency of the habitual energies is to reduce friction and consciousness, and to perform the function with a con-

stantly diminishing expenditure of force. This tendency is promoted and clinched by natural selection. When the action comes to be performed from nearly frictionless habit, and in unconsciousness, it is *instinctive.* Instinct expresses the net results upon the organism of a long line of superposed habitual actions. At one end of such line of habit is reason and consciousness, at the other end, unconscious instinct. Between the two extremes there is every possible gradation. The moment we begin the repetition of actions, we begin the establishment of instincts. After awhile an action will become semi-instinctive; that is, it will be performed in preference to another which is equally as reasonable, and it is liable to be preferred to one much more reasonable. A Mexican farmer, who all his life had used an antediluvian plow, with wooden mold board and a straight stick for a handle, was induced to buy a modern American plow, and the first thing he did with it was to saw off the bent parts of the handles. The formation of the instinct is the crystallization of the reason which started the habit in the first place. So that the cerebral action, which necessarily precedes the muscular action, is started by its accustomed stimulus, and performed with the minimum of attention; and consequently there being a minimum of blood supplied to the organs involved, they are not in condition to be influenced or changed by other stimulations, or considerations. In other words, the reason for the instinct has become so strongly fixed, that reasons against it cannot affect it. We say the person will not listen to reason. He cannot.

As we grow old our habits constantly tend toward this crystallization into instinct. When any action comes to be performed without conscious supervision, it is instinctive. We sometimes see an old lady knitting, and at the same time reading. Attention to the knitting is not required except in turning the corners, the movements in making the stitches having become instinctive. So a person may learn to play a number of tunes on an instrument so that the performance of any one may be instinctive. An amusing case in point was that of the lady who, while playing the piano for a social dancing party, fell asleep from the effects of a little too much "refreshment," and continued to play while entirely unconscious. She could be set going on any other tune with which she was familiar, by piloting her fingers through the first strain of the piece. This is instinct pure and simple; more so than we generally get it. Upon analysis, we shall find that both our own actions and those of other animals are usually mixed, being in part reasoned and in part instinctive. If the lady in the above anecdote had remained awake, she might still have done her playing instinctively and unconsciously, her attention being engaged with the movements of the dancers, or anything else; and the company would n-

have suspected that her playing was instinctive. So it is with the greater part of our actions. We can seldom do at once two things which both require attention, but we can do one requiring some attention, and at the same time several instinctive actions that require little or none. When a lady reads, her attention is directed to her book, but she may at the same time knit with her hands and rock the cradle with her foot. From this mixed nature of our actions, and the performance simultaneously of instinctive movements and those requiring attention, we fail to realize to how great an extent the former predominate over the latter. But they certainly do predominate, especially in old people.

But instinctive actions, or those tending to become such, are not confined to those which terminate in muscular motion. Muscular motion involves not only the muscle, but also its corresponding brain cells; so that the brain organ shares the instinct with the rest of the apparatus. But, as pointed out elsewhere, a great deal of the activity of the internal sense organs stops short of direct muscular movement. It ends in the establishment of the organs of ideas, which become standards or principles that influence and shade many of our actions, and direct the bent of new thoughts. These principles are liable, from long and uncontradicted attention, to become instinctive, and to be thrown into activity by very slight stimulations, and so influence other actions in an insensible manner. They color most of the actions of our lives, because almost every stimulation which comes into the brain, sets them going, and their reactions are cast with those of the rest in forming new ideas. Thus, ideas of honor may be instinctive, so that whatever stimulation comes to form new activities, these ideas interfere to give them their bias. Religious dogmas, and all sorts of superstitious notions, ideas of propriety and deportment, whimsical and odd notions, tricks and eccentricities, become instinctive.

A large proportion of our actions are mixed. A series of details which, taken together, may be called one act, will be purposive in part and instinctive in part. Thus, the Mohammedan notion of the duty and benefit of a pilgrimage to Mecca, becomes, in later life to most believers, an instinct. If strong and convincing arguments were presented the believer to prove the futility of such journey, and his opinion were changed thereby, he still would find it impossible to rid himself of the *feeling*. If he should undertake the pilgrimage thus instigated by a conviction grown to an instinct, the details of the preparations and of the journey would be worked out in small part by purposive actions, and in great part by instinctive ones. They are interspersed between each other. The carrying out of any large plan involves a great number of separate acts, the most of which, as the steps in walking, the motions of the hands in sawing, hammering, sewing, and the like, are all instinctive.

Instincts are transmissible by heredity. Those only partly formed transmit blind and ill-defined tendencies. A child may inherit a definite instinct for strong drink, or a vague indefinite instinct for adventure, which might be satisfied by adventure as a sailor or a soldier. It is seldom that one inherits opinions, but he inherits such form of cerebral organs as will be likely to develop in him the opinions of his parents, especially the more important ones, or principles. The reason of this, in part at least, is that specific opinions do not often become so fixed in the feelings and emotional nature as to be instinctive, till late in life, usually after the inheriting generation is born. So that what is transmitted is the tendency which the parent has in youth and middle age, to become what he does become in old age. A great many of our acts become instinctive very early, but they are not perfect until they receive a few lessons. We soon learn to dodge or duck the head to avoid a threatened blow or passing missile; we throw up the hands to screen the face and head, and throw them out before us if we are suddenly tripped up and in danger of falling, and we instinctly run when startled and confronted by sudden dangers of certain sorts. These are not instinctive to the new born infant; but because its inherited organization is adapted to them, it has only to be exposed a few times to the proper stimulation to cause them to become instinctive; just as the pointer dog usually requires a few lessons to lubricate and limber up his instinct for pointing. The instincts by which successive generations of particular families tend to fall into the same occupations, as sailors, fishermen, musicians, mechanics, thieves, beggars, &c., are of that partial incomplete sort which consist of strong tendencies, and will come into working order upon the first exposure to the appropriate stimulations, but which may be kept in the background indefinitely if such exposure be avoided. Sometimes, however, such instincts will assert themselves against education, the influence of friends, and the most obvious considerations of interest. Sucking, crying, and movements of limbs are instinctive at birth, and need no further education to become operative at once. But these are instincts which we outgrow, and which like the thymus gland, belong to childhood and become rudimentary (considered as instincts) when we reach maturity. Most of our instincts we grow into some time after birth. Among these are the sexual instincts, love of adornment and dress, language, modesty, and those mentioned above, relating to the opinions, principles, and occupations of adult life. Children are instinctively cruel, wanton, and destructive, in their small way, torturing insects and other small animals, breaking windows, &c. These instincts which we inherit from our savage ancestors are usually outgrown and we grow into others of a contrary nature, based upon the wider experiences of civilization. We thus illustrate in our individual lives, the evolution of civilization from savagery.

The instincts of the lower mammals are much more mature at birth than ours. A calf six hours old can walk without teaching, and is from one to two years ahead of the human infant in that respect. If the latter were prevented from trying to walk till three or four years old, it would probably be able to do it in one or two lessons, like the calf. That is, an instinct under construction at birth is sufficiently finished to be operative three or four years after. The instincts of the other animals are like those of men, in the fact that some are mature and operative at birth, and others come into operation later in life. This is simply that the reactions from the stimulating forces of the environment are different, as the organs become different in the course of growth.

We are accustomed to speak of the actions of the lower animals as instinctive, and our own as governed by reason. It is no doubt true that a greater proportion of theirs is instinctive than ours, but it is a minority in either case that is directly reasoned out. If a farmer appears at the gate of the pasture with a measure of oats, and calls his horse grazing within, a conscious reasoning process is set up in the brain of the horse, in which the oats on one side are weighed against contrary inducements. If he concludes to obey the call, the stimulation sets up the instinctive motions of the legs required to take him. Analyze all the actions of horse or man and we find them composite like this. The turning or governing points are apt to be reasoned; that is, determined by the strongest of antagonistic motives after a struggle between them, which takes time, and commonly arouses consciousness. The filling in between these governing corners is performed by the instincts, which may be defined as so many questions *settled*, which, therefore, are no longer open to argument, and which may proceed to action without arousing consciousness of themselves.

We are apt to overrate the amount of reasoning which enters into human action, because we are liable to think of the works of *man* as the works of *a* man, or as the ordinary functions of any human brain. Of course we know better the moment we reflect. The small contribution which any one person makes to the common stock of ideas, is not enough to make him an exception to the rule that a large part of both ideas and actions are instinctive. The greater part of the ideas which finally become instinctive with us, are not reasoned out by us in the first place, but are imparted to us as part of our education. A great many are drilled into us in youth, and often become so firmly fixed as never to be questioned or questionable in after life. The possibility of doing this is at the bottom of the struggle for the control of the education of the youth in this country and Europe. Where these introduced instincts relate to duty and obligation, they constitute our *conscience*, and their occasional violation causes that uneasiness called *remorse*, while

their frequent violation begins that subversion of them called *searing* the conscience, which ends by the substitution for them of entirely new habits of thought.

Although every instinct is or has been reasonable, there are many that never were *consciously* reasoned out. They are results of the automatic reactions of the lower centers, the basal ganglia, cerebellum, medulla, &c. It is to this class that most of our earliest instincts belong, and they constitute the principal part of the instincts of the invertebrates. They include all those muscular combinations that are necessary to us in our common activities of walking, handling, seeing, eating, &c., and to other animals in swimming, climbing, leaping, flying, &c. They in general have to be learned, although some are nearly perfect in a very few lessons.

The mental instincts of animals are largely acquired like those of man. The young of mammals and birds are taught by their elders in many accomplishments and movements in hunting, &c.

Instincts are not only built up by habitual stimulation, but when the stimulation becomes changed, the instinct is liable to be undone. Instincts which are too firmly grounded to yield to such changed stimuli, become impediments and hindrances. Geology shows the extinction of vast numbers of species brought about by conditions changed too suddenly to allow the modifications of the instincts to suit. On the other hand, it shows innumerable instances in which the geological changes were slow enough to allow the modifications of animal instinct to keep up. When instinctive habits are of little importance, either as aids or hindrances, they may survive a long time after they have become useless. This is illustrated by the persistence of wild habits in animals after their domestication; such as the hiding of their nests by fowls, the hiding of her new born calf by the cow, the turning around of the dog before lying down to sleep, &c. Dogs will turn around thus a number of times and scratch the surface, no matter if it be a carpet or a pavement, as if they were tramping down the grass and scooping out a hollow in the ground, in the manner of their wild ancestors. A semi-idiotic dog, probably a reversion toward an ancient type, was observed to turn around on a carpet thirteen times before lying down. Jackals, fennecs, and other allied animals in the zoological gardens, turn around in their straw, and make their beds as they would do in prairie grass, or leaves in the woods.

It is well known that cats bury their excrements of both kinds. A kitten was seen scraping ashes over a spoonful of pure water spilt on the hearth. Dogs, wolves, and jackals have not this habit at present, but there is reason to believe their remote ancestors had, for they all make a pretense of covering their excrement by scratching with all four feet as if to heap up a mound of earth; and they do this on a pavement.

Wild habits also survive in tame birds. "The sheldrake (Tadorna) feeds on the sands left uncovered by the tide, and when a worm-cast is discovered it begins patting the ground with its feet, dancing as it were, over the hole, and this makes the worm come to the surface. Now Mr. St. John says, that when his tame sheldrakes came to ask for food, they patted the ground in an impatient and rapid manner. This, therefore, may almost be considered as their expression of hunger. Mr. Bartlett informs me that the flamingo and the kagu (rhinochetus jubatus) when anxious to be fed beat the ground with their feet in the same odd manner. So again, kingfishers when they catch a fish always beat it until it is killed, and in the zoological gardens they always beat the raw meat with which they are sometimes fed, before devouring it." (Darwin, Emotions 47).

We often speak of the instincts of animals as unerring; but this is a mistake. If a man wishes to jump a ditch, he instinctively estimates its width and regulates the force necessary to carry him over. If it is a little too wide and he has to make a run for it, he instinctively estimates the length of the run, and regulates his steps so as to bring the right foot upon the spot from which the spring is to be made. In such things as these the instincts of other animals are like our own, some better and some worse. But in the more complicated instincts which include cerebral memories, and involve many organs, the lower animals are by no means infallible. For example, the instinct of a rattle-snake encourages him to attack a hog, with invariable disaster,—to the snake.

The migratory instinct which has been fastened upon large numbers of birds, fishes, and mammals, including some races of men, by the changes in the seasons, is complicated with conscious memories. A bird from Spain will find the same nest in an English hedgerow that it occupied last year. The instinct of direction in Indians and half-breeds has been mentioned. Wrangel observed the remarkable perfection of it among the natives of North Siberia in finding their way through a labyrinth of ice hummocks, and continually changing direction without getting lost. The wild goose in going north travels in the night and across the ocean. Still this instinct is not unerring either in man or other animal. The Indian packers of an engineer's outfit in northern Wisconsin all got lost one cloudy day. European birds get lost and reach the Azores sometimes, and North American birds lose their bearings and stray to Ireland. Swallows often get lost. Fishes, too, get off the track. Salmon frequently get into the wrong river, "many Tweed salmon being found in the Forth." Certain sheep in Scotland and Spain want to migrate every spring, as no doubt their wild ancestors did.

The instincts of insects are similar in their nature to those of other

animals. "One solitary wasp, *sphex flavi pennis*, which provisions its nest with small grasshoppers, when it returns to the cell, leaves the victim outside and goes down for a moment to see that all is right. During the absence of one, M. Fabre moved the grasshopper a little; out came the sphex, soon found her victim, dragged it to the mouth of the cell, and left it as before. Again and again M. Fabre moved the grasshopper, but every time the sphex did exactly the same thing until M. Fabre was tired out. All the insects of this colony had the same curious habit. But on trying the same experiment with a sphex the following year, after two or three disappointments she learned wisdom by experience and carried the grasshopper directly down into the cell." (Lubbock, Senses of Animals.) Another species of sphex, *tachytes nigra*, which usually "makes its own burrow and stores it with paralyzed prey" for its own larvæ, will occasionally take possession of the burrow and provisions of another sphex, and appropriate them to her own purpose. There is a caterpillar that usually weaves a little silk web to attach the chrysalis to. But if such a caterpillar be placed in a box with a piece of muslin stretched across for a lid, she will omit her web, and attach the chrysalis directly to the muslin.

The above are examples of instincts modified by intelligence. In most actions, as observed before, we find both of these elements.

"The larva of a beetle (cionus scrophulariæ), when bred on the scrophularia, exudes a viscid substance which makes a transparent bladder, within which it undergoes its metamorphosis, but the larva when naturally bred, or transported by man onto a verbascum, becomes a burrower, and undergoes its metamorphosis within a leaf. In the caterpillars of certain moths there are two great classes, those which burrow in the parenchyma of leaves, and those which roll up leaves with consumate skill," yet they belong to the same species. These cases of contingent instinct show that instincts are reactions against stimulations in the environment, and must differ either intelligently or instinctively when the stimulations differ. Many birds which are quite tame to man in a state of nature, are very wild in countries that are inhabited, showing a change in their instincts by the presence of man.

Darwin also found a sort of water lizzard which has been driven to live on land by the presence of sharks and other enemies inhabiting the water. It lives on water plants, but remains out of the water as much as possible. When he threw one into the water it scrambled out again, being less afraid of him than its aquatic enemies.

Edible bird's nests vary greatly in structure. The collocalia, the bird which makes the edible nests, belongs to the same sub-family with the swift They have salivary glands that secrete a sticky, mucilaginous, brittle substance, by which they fasten together the parts that compose

the nest. Some varieties stick the nest to a wall or chimney, and the amount of saliva used is greatly varied in the different species, being small in the European species, larger in the North American, and largest in the Asiatic genus.

The houses of muskrats and beavers vary in structure according to the necessities of the case.

Some bees when near the sea burrow in sand banks; the same species when in wooded districts bore holes in posts.

Some insects have different "instincts under different circumstances, or at different times of life."

The force of heredity is curiously shown in hybrids, where the instincts of both parents are exhibited in the offspring. A case is given of a young dog, the son of a springing spaniel and a setter, that raised a partridge in *silence*, as its male parent would have done, and a couple of hours later started a woodcock with barking, as its female parent would have done.

It often happens that a person will fall into some queer trick or habit which is seldom graceful and is apparently useless. One man in meditation will sit and twist and tug at his beard, and the more intently he thinks, the harder he will twist. Such habit begins through the overflow of superfluous excitement upon an easily moved muscular combination, producing an automatic trick. Sometimes such tricks become so instinctive as to be hereditary. A case is related of a gentleman who had a trick in his sleep, when on his back, of slowly raising his right arm up above his forehead, then dropping it suddenly, bringing the wrist heavily down upon the bridge of the nose. He would keep this up for an hour at a time and several nights in succession, and repeat after an interval of several nights. This trick was quite faithfully inherited by a son, in whom it appeared after he had reached maturity. A daughter inherited it in a modified form, bringing the hand, instead of the wrist, down upon the nose, and striking it rapidly. Her spells were at intervals of some months.

Akin to the above is the inheriting of hand-writing, which depends on the exact repetition in the child, of the cerebral organs necessary to produce the characteristic muscular combinations. In a family named Cobbe, the same characteristic writing was transmitted through five generations, one member writing it with his left hand. With a little practice almost anyone can learn to write *backwards* with his left hand. When such writing is held up to a looking-glass it can be read forward, and will be found to have the same peculiarities as that executed by the right hand. This fact is held to prove that the brain is responsible for the instincts of the hand-writing rather than the muscles.

Norwegian ponies are trained to obey the voice, and are very docile

when they understand, but are very hard to train to the bit, the race not having inherited that disposition.

A cat, taught to beg like a terrier, transmitted the trait to its kittens, which did the same, though scattered to several owners before they ever saw the act performed.

Tameness results when the environment of the animal includes man and his surroundings. Both tameness and wildness are instincts, and may be lost, or acquired by hereditary use. Rabbits are very wild when wild, and very tame when tame.

The young of wild and tame ducks hatched in the same nest, show their instinctive wildness and tameness as soon as they are out of the shell. Of habits far gone in the process of crystallization into instincts, there are many both of race and family. The tendency of all long established human societies is to fall into grades and castes. We can easily imagine that the four castes which obtained in India, if never disturbed, would, in time, have become instinctive, so that the feelings of each individual would be a sufficient indication of his social status.

Instinctive, or partially instinctive modes of thought are accounted for in the same way that physical instincts are, that is, a certain structure of brain being inherited, the action most natural to that brain is the action that differentiated and formed the brains from which it is descended. So a religious habit of thought in an ancestral line may beget a religious tendency, or instinct in the descendants. Such instincts have often been cited as evidence of the reality of a relationship existing between ourselves and a supernatural being. But obviously they prove only that the ancestors *thought* there was such a relationship; which thought differentiated organs that became hereditary.

Among the human habits which may be regarded as instinctive, are the feelings of superstition, which dominate all savage and semi-savage races, and to which even civilized and enlightened races are frequently liable to lapse, and which are strong in all recently civilized barbarians; as for example, the African race in America, the Sandwich Islanders, &c. The aversion to work on the part of the males of some of our wild tribes of Indians, in spite of precept, example, and education is, no doubt, instinctive, as well as the industry of the women.

In discussing mental phenomena under the various titles which we give them, of reflection, instinct, automatism, intelligence, consciousness, &c., we must not lose sight of the fact that these terms serve only to point out pecularities, aspects, or subordinate qualities attending the manifestations of the forces of the environment in their assaults upon the brain. They all result from these assaults and are all simply new forms of the energy. They are movements, depending for their peculiarities on the peculiarities of the things that move, but they are

not *things* either in motion or still. Thus, derived from a common origin, they are of a common nature in their essential working qualities.

CHAPTER LXXIX.

TELEPATHIC TRANSFER OF BRAIN ACTION.

From the facts set forth in the chapters on Polarity and Electricity, we have reason to conclude that there is a *Field of Force* surrounding every body in which electric tensions are generated; and that, practically means every body in existence, by no means excepting organized bodies. There is the strongest reason to believe that the analogy between magnetism and nervous force is the same as that between the vibrations which produce red and those which produce blue; that is, they are different tones of the same sort of motion. In addition, therefore, to the magnetic field adout an organized body, there is also by analogy the nervous field, or rather, perhaps, the field of nervous tones. If the body radiate heat, there is a field of heat tones and there is also the field of the tones of the color which the body reflects. It might be reasonably anticipated that when two organic bodies are brought near to each other, so that their fields of force overlap or infringe, the disturbance thus caused in the field of force would react upon the nervous currents and tensions in the interior of the body itself, disturbing and rearranging them. This inference is strongly supported by numerous facts to be hereinafter cited. The disturbing forces, it must be inferred, constantly produce their effect even when there is no consciousness of it. But delicate as these forces are, their operation is, nevertheless, often sufficient to produce the most startling effects upon consciousness. However, there is reason to think that in the case of man, the subtile influence which is almost constantly at work, produces effects in a silent and imperceptible manner entirely unperceived by consciousness. For, after being exposed to the influence of a certain presence for a time, it often happens that we suddenly become aware that new feelings have been produced in us, such as aversion or attraction, love or dislike, &c. And this happens when it cannot be attributed to the effects of any oral communication, although there is generally a possibility of the influence of the expression of the countenance and actions of one person upon the imagination of another, even when no words are spoken. But after making allowance for that, too, there is reason to believe in a residual influence independent of the ordinary senses. It has often been remarked that a person sitting in an audience has been influenced to turn around when a friend sitting some distance back has strongly concentrated his attention upon him. Thoughts of a person who has not been

in mind for some time and whose presence is not expected, have suddenly sprung up, and often soon been followed by the appearance of the person thought about. This has happened so frequently as to give rise to the homely proverb, "Think of the Devil and he is sure to appear." In such case we may suppose the visiting person has perhaps unwittingly sent before him thoughts of the friend he is going to see, and thus aroused in him a reciprocal impression. There is strong indication from some of the cases to be cited, that the influence from one nervous system to another is sometimes projected over a considerable distance, the parallelism between nervous and electric action remaining, in this respect, as well as in regard to the fields of force. This has been named Telepathy and it may be spontaneous or purposive.

Comparatively recent investigations by the Psychical Research Society, and other inquirers, seem to point to this conclusion, that there is such a thing as the disturbance of the cerebral conditions in one brain by the activities of another, directly, without the mediation of either of the five senses. If A has in his brain an organ which gives him the sensation of a certain fact that he wishes to communicate to B, the ordinary process is like this. A current passes from A's organ down the nerves to the tongue, lips and larynx, whose movement communicates motion to the air which, striking on the auditory fixtures of B, creates a current into his internal senses and builds up an organ similar to the one in A, from which the movement started. Now this operation goes on every minute in the day. We are constantly building up in each other's internal senses, organs as near like our own as we know how to make them by word painting. Again, two things which are each like a third thing, must be like each other. If two men see a statue, the object will differentiate an organ in each brain, and the two organs must be much alike. The same is true, if the two hear the same musical instrument or inhale the same odor, or touch the same surface, or taste of the same dish.

From the fact that these paired organs, one in one brain, and one in another, were formed by nearly identical stimulations and can be reagitated by the same, it would seem antecedently credible that if some element extended from one to the other to act as a vehicle, the vibrations resulting from the activity of one might communicate a similar activity to the other; as the vibration of a string in one piano may cause the vibration of its corresponding string in another. As to the vehicle, we have convincing evidence that the universal Ether *is* universal, and bridges the distance between every two brains, however long or short it may be. In telegraphing to and from running trains, the air alone is the conductor over a space equal to the distance of the telegraph wires from the track. This is usually from 30 to 50 feet, but instances have been reported in which the experiment was successfully conducted when this distance was 400 feet. This is remarkable considering the greatness of

the inertia of even the most delicately constructed electric instruments. The disturbance of the tensions must be enough to enable the straining ethereal element to carry with it the heavy metallic armature. The delicacy of the adjustments of the cerebral receiving organs must be infinitely finer than this.

The following is told and vouched for by Abercrombie: "A lady in Edinburgh had sent her watch to be repaired. A long time elapsed without her being able to recover it, and after many excuses she began to suspect that something was wrong. She now dreamed that the watchmaker's boy, by whom the watch was sent, had dropped it in the street and injured it in such a manner that it could not be repaired. She then went to the master, and without any allusion to her dream, put the question to him directly, when he confessed that it was true."

Another singular case which Abercrombie cited as true, is as follows: A young man at an acadamy a hundred miles from home, dreamed that he went to his father's house in the night, tried the front door but found it locked, got in by a back door and went to the bedroom of his parents. He then said to his mother whom he found awake, "Mother, I am going on a long journey and have come to bid you good-by." On this she answered under much agitation, "Oh, dear son, thou art dead." As was afterwards ascertained his mother dreamed the same dream at the same time, the particulars of someone trying first the front door, then entering by the back door, of the person whom she then recognized as her son approaching her bed, and using the same language, and her reply being the very same as in the son's dream. The dream gave the mother much alarm, but nothing unusual happened to either of the parties.

This curious occurrence cannot be explained as a mere accidental coincident. In fact, I cannot imagine any possible explanation which does not involve the projection of nervous influence to a distance. We may suppose a high degree of sameness or identity between the two organizations, which is sensible to us under the name of sympathy. All organizations which have been exposed to the same stimuli are obviously, to a certain extent, identical in constitution, so that whatever form of energy is able to excite one of them, will excite the other, if by any means it can reach it; and whatever form of energy is developed in one, if by any means we may suppose it projected into the field of force belonging to the other, it will develop in it a movement precisely like that which took place in the first. The two nervous organizations stand to each other in the very same relationship as two connected dynamos, one of which is driven by a steam engine, while the other is operated by the current from the first, and in turn drives some sort of machinery, as a printing press or a street car.

The following is another instance: "Columbus, Ohio, Jan'y 3.

Something impelled John Pembridge, an employe of the machine works, this morning, to leave his work and go home. He says he does not know why he did so as he was not sick. Arriving at his home, where a grown daughter, his only child, kept house for him, he found her dead. He had left her in her usual good health in the morning. The cause of her death, and its premonition by the father, are mysteries."

The following cases are furnished by the authors of "Phantasms of the Living." Mrs. Severn, wife of Arthur Severn, writes from Brantwood Coniston, under date of Oct, 27, 1883, that one summer morning, about 1880, she awoke at seven o'clock with a start, feeling as if she had received a hard blow upon the mouth, which drew blood, and with such impression she pressed her handkerchief to the part. After a few seconds, upon removing the handkerchief she was surprised to find no blood, and so concluded it had been a very vivid dream. About two and a half hours later, her husband returned from an early sail upon the lake, during which, on account of a sudden squall, he had received a blow upon the mouth from the tiller, which gave a rapid whirl as the boat was turned by the squall. The wound drew blood, which he stanched with his handkerchief. Upon comparing notes it was perceived that the wound must have been inflicted about the time the lady's dream occurred, and no doubt it was at the same instant.

On the evening of the 25th of March, 1880, at 8:30 o'clock, Mr. Richard Wingfield-Baker, of Orsett Hall, Essex, England, died from the effects of a fall he suffered while hunting with hounds that day. The same night, but several hours later, his brother, Frederick Wingfield-Baker, living at Belle Isle en Terre, Cotes du Nord, France, had a dream, which he relates as follows: "On the night of Thursday, the 25th of March, 1880, I retired to bed after reading till late, as is my habit. I dreamed that I was lying on my sofa reading, when, on looking up, I saw distinctly the figure of my brother, Richard Wingfield-Baker, sitting on the chair before me. I dreamed that I spoke to him, but that he simply bent his head in reply, rose and left the room. When I awoke I found myself standing with one foot on the ground by my bedside, and the other on the bed, trying to speak to and to pronounce my brother's name. So strong was the impression as to the reality of his presence, and so vivid the whole scene as dreamt, that I left my bedroom to search for my brother in the sitting-room." Three days after this he received the information of his brother's death. (Phantasms, 1-199.) The circumstance of the postponement for some hours, of the consciousness of the impression, is plausibly explained by the authors of Phantasms. The impression is doubtless made at the moment in which the event happens, but the succeeding automatic cerebral processes by which the undefined impression is transformed into a

definite idea or image, is carried on, as it always is, in unconsciousness, and remains in abeyance while the consciousness is occupied by the more aggressive images derived through the ordinary senses. When night comes on, and the senses no longer transmit impressions to the brain, the suppressed telepathic image emerges into consciousness in the shape of a subjective vision or a vivid dream.

Jan'y 3d, 1856, the steamer Alice was tied up to the shore of the Mississippi, just above New Orleans. Her commander, Joseph Collyer, had retired for the night, but being suddenly warned of the near approach of another steamer coming up the river, he rushed out upon deck in his night clothes. At that instant the upward-bound steamer, named the "Red River," collided violently with the Alice, and caused her flag-pole to fall over. It struck Mr. Collyer on the head, splitting his skull and killing him instantly. His parents resided at Camden, New Jersey, more than 1,000 miles from the scene of the accident. Yet, about the moment it happened, as nearly as could be ascertained afterwards, his mother, feeling uneasy, sat up in bed, and upon looking round the room, as she says, 'to my utter amazement saw Joseph standing at the door looking at me with great earnestness, his head bandaged up, a dirty night-cap on, and a dirty, white garment on, something like a surplice. He was much disfigured about the eyes and face." She was of course much alarmed, and felt sure, as she told the family, that they would hear bad news from Joseph. It was thirteen days, however, viz., on the 16th of Jan'y, before the slow mails of that day brought them the fatal news. Mrs. Collyer's account of her vision is dated March 27, 1861, or five years after the occurrence. If it is to be explained as a transference of a mental state from Joseph as the agent, to his mother as percipient, it must be observed that probably the lady may have unconsciously incorporated with her recollections of the vision, some things that she learned afterwards. This is especially probable in regard to the bandage around the head, which, it is said, was not put on till some time after the accident. (Phantasms, 1–204.)

In 1883, two friends, who are known by the initials N. J. S. and F. L., respectively, were employed together in an office. Their friendship had lasted for eight years, and was of a very warm and intimate character. On Monday, March 19th, F. L. complained of being unwell, and during the week received some medical treatment; on Saturday he was not able to come to the office, and that night, a little before nine o'clock, he died at his home from rupture of the aorta. Saturday evening N. J. S. was sitting at his home. He had had a headache, and mentioned to his wife that he was unusually warm. Immediately afterwards he saw his friend, F. L., standing before him, dressed in his usual manner. "He looked

with a fixed regard at N. J. S., and then passed away. N. J. S. immediately informed his wife what he had seen, and asked her the time. It was 12 minutes to 9. It could not be known precisely at what time F. L. died, as he was alone, but it was between 8:35 and 9.

Under date of Nov. 1884, Mrs. Bettany, of Dulwich, Eng., writes the authors of Phantasms, as follows. (Vol. 1, p. 194). "When I was a child, I had many remarkable experiences of a physical nature, which I remember to have looked upon as ordinary and natural at the time. On one occasion (I am unable to fix the date, but I must have been about 10 years old) I was walking in a country lane at A, the place where my parents then resided. I was reading geometry as I walked along, a subject little likely to produce fancies or morbid phenomena of any kind, when in a moment I saw a bedroom, known as the white room in my home, and upon the floor lay my mother, to all appearance dead. The vision must have remained some minutes during which time my real surroundings appeared to pale and die out; but as the vision faded, actual surroundings came back, at first dimly, and then clearly.

I could not doubt that what I had seen was real, so instead of going home, I went at once to the house of our medical man, and found him at home. He at once set out with me for my home, on the way putting questions I could not answer, as my mother was to all appearance well when I left home. I led the doctor straight to the white room, where we found my mother actually lying, as in my vision. This was true, even to minute details. She had been seized suddenly by an attack at the heart, and would soon have breathed her last but for the doctor's timely advent. I shall get my father and mother to read this and sign it. Jeanie Gwynne-Bettany."

"We certify that the above is correct.

S. G. Gwynne,
J. W. Gwynne."

Some cases are recorded in which there are two percipients moved by the same agency. (The *percipient* is the person who receives the impression or sees the vision, while the *agent* is the person from whom it comes.)

Sarah Eustance, of Stretton, Eng., died on July 3d, 1866, aged 45. Twelve or 14 hours before her death, she expressed an intense longing to see once more her brother-in-law, John Done, to whom she was much attached, and whom she familiarly addressed as "uncle," and his niece, Rosanna, who lived at a distance of 12 or 13 miles. At the time indicated, Mr. Done, who had been asleep, awoke, hearing a voice distinctly call him, "Uncle, uncle, uncle!" He, thinking it was Rosanna who had called him, went to her room, and found that she too, had been awakened by some unknown influence, and heard a voice call dis-

tinctly "Rosy, Rosy, Rosy!" She supposed it was her uncle Done, who had called her, as they two were the only occupants of the house that night. (Phantasms of the Living.)

This seems to be a proper place to observe, that in many cases of telepathic transmission, there is much more in the vision, or hallucination of the percipient, than could have been in the consciousness of the agent. In the case of Mrs. Bettany, for example, it is quite unlikely that the details of her mother's situation and surroundings in the "white room" would all have been present to the mind of the mother, and so become a part of the transmitted impression. In general, in cases of vision, it is not possible that the agent is often thinking about the clothes he has on, much less those he may have worn in former years. Yet it is often in these latter that he appears to his percipient. The fact is, the vision is made up oftentimes chiefly, or largely, of elements which were already in the mind of the percipient, and yet could not have at the time been in the mind of the agent. It is inferred, therefore, that the actual transmission may consist of a single one, or of only a few vibrant elements, which serve to arouse in the brain of the the percipient the disturbance of a mere point of cerebral substance. From this point the disturbance spreads into the related memory organs, and there is at once an image constructed on the same principle on which dreams in common are formed. It is not often that the percipient sees the agent (in imagination) as he really is at the moment. In the case of the appearance of F. L. to N. J. S., cited above, the spectre appeared in his "hat with a black band, his overcoat unbuttoned, and a stick in his hand." The sick man was seen by his brother at about 8:40, within a few minutes of his death. He was then sitting in his bedroom, where he had been for some time under treatment, and probably was not attired with hat, overcoat, and cane.

These accessories were supplied from the memory organs of N. J. S. The transmitted impression from the agent F. L., amounted only to a suggestion, and initiated the disturbance in the brain of N. J. S., which, overflowing to the related organs, aroused their action, and a new image was constructed, embodying the instant impression with the former impressions, and, as it were, redating the result of the latter. Immediately after the vision, N. J. S. announced the same to his wife, and said further, that F. L. was dead, for he had just seen him. The conviction that he was dead, seems to have been the result of his own reasoning, rather than a part of the original impression. It has happened so often that visions of this sort have occurred at the time of the death of the agent, that every one is familiar with such coincidence, and, immediately upon the occurrence of such vision, would be likely to infer a death. The case related by Abercrombie, of the simultaneous dream of

mother and son, in which the mother exclaimed: 'Oh, dear son, thou art dead!'" shows the tendency to form this inference whether there is any ground for it or not. Cases are cited in "Phantasms" in which the percipient, upon seeing the agent, has concluded as a matter of course he was dead, when it was not so.

In the case last cited above, in which the agent felt a strong desire to see two persons, each person felt the effect of that part only of the agent's longing which concerned him or her, Mr. Done hearing his name only, and Rosanna hers. Obviously, the different organs of the brain each developed by and attuned to a particular pitch, are restimulated only by vibrations in their proper pitch, and supposing that in the above example the same series of tones came to both the percipients, some only of these tones could affect one of them, while others would affect the other.

It cannot, in the nature of things, be otherwise than that we are all of us constantly assailed by the mental exhalations of other people, and it is hardly possible that we escape being sometimes influenced by them. It is a matter of at least plausible conjecture that sometimes when we are in a passive state, either waking or sleeping, our thoughts receive unconscious influence from these wandering stimuli. While there are instances of the transference of ideas of a happy nature, such as a wedding, it is remarkable that the great majority, in fact almost all the observed cases of spontaneous telepathy, relate to death, illness or accident. From this, the authors of Phantasms infer that pain is more vivid than pleasure. It may be suggested that when in pain, especially hopeless pain, the agent is in a condition demanding and longing for help and sympathy. The mind goes out of itself to seek for the support which fails within. On the other hand, I take it, we as percipients are more impressible by painful than by pleasurable emotions. We are more passive and negative toward them because our attention is ordinarily not occupied with our own pains, but our own pleasures. This would not be true if pain on the whole predominated over pleasure in our lives. Lastly, the pleasurable impressions we may chance to get, may fail of interpretation by being confounded with our own, and unrecognized as having an extraneous origin.

The experiments made by the Psychical Research Society, of London, are of very satisfactory and convincing nature, settling beyond reasonable doubt the fact of purposive thought transference. The two principals concerned are the Agent, who concentrates his mind on the idea he wishes to transfer, as the name of a person or a card, a color, a picture or whatever he pleases, and the Percipient, or reader of the thought of the agent. The agent must expend considerable energy in keeping up the necessary concentration. The percipient must become as passive as

possible, and thinking his own thoughts as little as possible, must assume a condition of expectancy, awaiting the impression from the agent. If there are several persons in the room the effect is better when they assist the agent by concentrating their attention upon the same idea. This operates to strengthen the force of the impression and at the same time to eliminate the element of distraction which might arise from the presence of other impressions. If the percipient is blindfolded, the distracting impressions which he might get from things seen are eliminated. He may be still further insulated if his ears are stopped. Children and females generally make the best percipients. Generally the best effects are obtained when the agent and percipient are close together or even in contact. Contact is made by the hands, or by the agent touching the head, neck or some other part of the percipient. A connection between the two with a stick or piece of wire is sometimes better than nothing, though a great number of successful experiments have been performed without visible connection of any kind. "Practice makes perfect" in this sort of exercise as in every other. There is reason to believe that the faculty is possessed in some degree by almost every one, but it is much more highly developed in some than in others. The fact that it can be cultivated involves also the reverse. It may be lost by disuse, and the conjecture is ventured here, that since the development of articulate language, there has been such a loss to the human race.

The experiments made by the P. R. Society consisted of the attempted transference of various sorts of ideas, embracing in short, ideas of all classes; viz.:

(1) Ideas of direction and locality. These I take it are among the easiest to transfer, and consist in hiding objects which the percipient is to find, and in thinking of localities to which he is to go, &c.

(2) Visual impressions; the forms of objects, such as drawings or pictures, figures, alphabetic and geometric characters, cards, &c. The agent makes these characters, or keeps his attention fixed upon them by looking steadily at them or otherwise, when the percipient is, or should be, able to describe them or reproduce them on a slate or paper. The transference of the idea of a color comes under this head.

(3) Other sense impressions; as smell, taste, hearing, &c., sounds of words, names, sentences, tunes, &c. In the transference of many sensations there will of necessity be a blending of different senses, to a greater or less extent. For example, when the agent draws a card from a pack, he naturally is himself impressed by its appearance, form, color, &c., visual impressions, and also by its name, which is an auditory impression aroused by association. The transfer to the percipient is therefore two mingled impressions.

(4) Impressions from the internal senses. (*a*) Emotional, as pain,

pleasure, anxiety, fear, &c. (*b*) Intellectual; as concrete ideas, such as dramatic and historical scenes, apparitions, &c., and abstract ideas.

The success had in the purposive transfer of ideas of all the above classes in the experiments of the P. R. society, is sufficient, independent of the hundreds of spontaneous cases which they have collected, to fully justify the conclusion that such transfer is real. Of course, not all, nor even a majority of the experiments have been successful, but so large a percentage have been, that the results are unaccountable on any other theory than that of telepathic transference.

In 497 trials tabulated by the experimenters, in which playing cards, numbers and words were thought of by the agent, and guessed by the percipient, the results were as follows, two guesses being allowed when the first was unsuccessful:

Cards: 260 trials; guessed right on first trial 29 times, on second trial 18 times, total, 47.

Numbers, &c.: 187 trials; guessed right first time 41, second time 17, total, 58.

Words: 50 trials; guessed right first time 25, second time 10, total, 35; grand total, 140 successes in 497 trials, or 95 correct guesses at first trial in 497, or nearly 20 per cent. The probability of obtaining such result by the operation of mere chance, is not one in thousands of millions of times. It happened at one time that there were nine complete, and two partial successes in fourteen trials, at another time there were eight correct guesses in succession.

In experiments for the transfer of taste, strongly tasting substances were selected, such as vinegar, mustard, Worcestershire sauce, wine, aloes, alum, nutmeg, pepper, ginger, &c., and these were tasted in another room by the agent, who afterwards touched the percipient, in some cases through a hole in a partition, the parties being in separate rooms. The proportion of correct answers was large, and in some cases there appeared to be a transference of smell as well as taste impressions. The two senses are intimately related, taste being often at fault when not supported by smell. During experiments in tasting, for example, the agent smelled eau de cologne, and the percipient, though expecting a taste sensation, experienced and reported the effect of cologne. Pain impressions were likewise in many cases strikingly transferred.

The following table of 20 trials shows the method and its results. The percipient, a lady, was blindfolded, and seated with her back to the agents, of whom there were three or more, and who inflicted on themselves, simultaneously the same pain on the same part of the body.

1. Back of left hand pricked. Rightly localized.
2. Lobe of left ear pricked. Rightly localized.
3. Left wrist pricked. "Is it the left hand?" pointing to the back near the little finger.
4. Third finger of left hand tightly bound round with wire. A lower joint of that finger was guessed.

5. Left wrist scratched with pins. "It is in the left wrist like being scratched."
6. Left ankle pricked. Rightly localized.
7. Spot behind left ear pricked. No result.
8. Right knee pricked. Rightly localized.
9. Right shoulder pricked. Rightly localized.
10. Hands burned over gas. "Like a pulling pain; then tingling like cold and hot alternately." Localized by gesture only.
11. End of tongue bitten. "It is in the lips or the tongue?"
12. Palm of left hand pricked. "Is it a tingling pain in the hand, here?" placing her finger on the palm of the left hand.
13. Back of neck pricked. "Is it a pricking of the neck?"
14. Front of left arm above elbow pricked. Rightly localized.
15. Spot just above left ankle pricked. Rightly localized.
16. Spot just above right wrist pricked. "I am not quite sure, but I feel a pain in the right arm, from the thumb upwards to above the wrist."
17. Inside of left ankle pricked. Outside of left ankle guessed.
18. Spot beneath right collar-bone pricked. The exactly corresponding spot on the left side was guessed.
19. Back hair pulled. No result.
20. Inside of right wrist pricked. Right foot guessed.

Thus in 10 out of 20 cases the percipient localized the pain with great precision; in six the localization was nearly exact, and with these

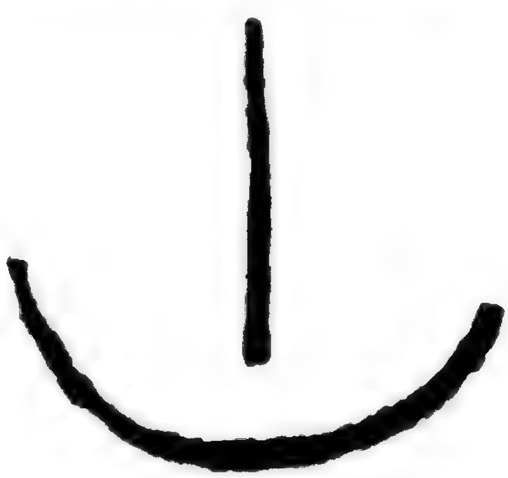

FIG. 383.

FIG. 384.

FIG. 383.—Original by the agent, Mr. Guthrie, who also drew 385, 387, 389, 391 and 393.

FIG. 384.—Reproduction of 383, by Percipient, Miss Edwards, who also drew 386, 388, 390, 392, 394.

FIG. 385.—Original.

FIG. 386.—Reproduction of 385.

we may include No. 10, where the pain was probably not confined to a single well-defined area in the hands of all the agents; in two, no local impression was produced; and in one, the last, the answer was wholly wrong."

In the transference of ideas of drawings, some of the experiments were very curious. Drawings shown in figs. 383 to 394 inclusive, represent the whole work of a single sitting; the percipient sitting with her back to the agent, and not in contact at any time during the experiment. There was of course special care that the percipient should get no knowledge of the nature of the originals through the ordinary senses

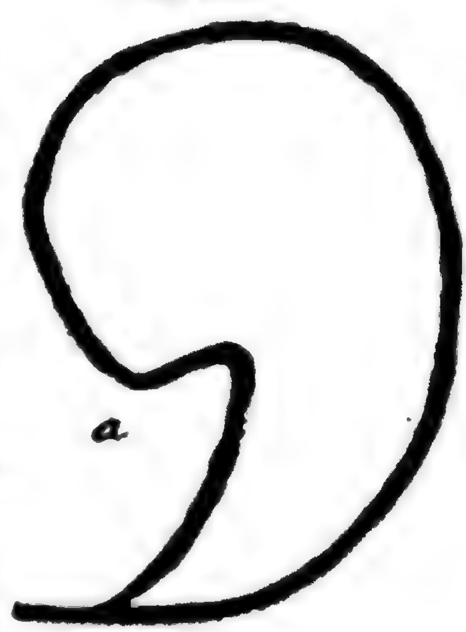

FIG. 385.

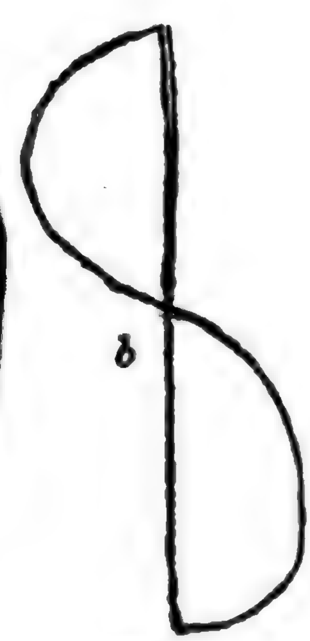

FIG. 386

In fig. 398, the reproduction of 397, there is shown the singular phenomenon of inversion. There were a number of such cases. The same phenomenon was stated by Washington Irving Bishop to occur to him in certain cases. Thus, in a public exhibition of his "mind-reading" powers at Minneapolis, the committee, as "agent," saw on a bank note the number 215,298.85, which Bishop reproduced as 215,268.58. This was a remarkable reproduction. In regard to the change of position in the last two figures, and the inversion of the figure 9, making 6 of it, he explained "that things came to him inverted like the picture in a camera." Other of Mr. Bishop's performances were as follows: A gentleman, having written a name upon a piece of paper, and inserted it in an envelope, went into the foyer of the theater and took hold of a copper wire, the other end of which was wrapped around Mr. Bishop's head, who soon wrote upon the blackboard with chalk, the name which had been placed in the envelope, and in a style of chirography almost a fac simile of what was written. A committee-man then thought of a tune, and Mr. Bishop immediately played it on the piano.

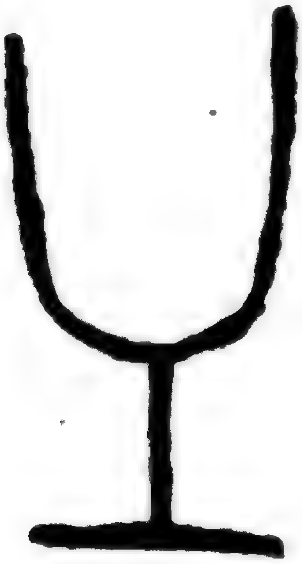

FIG. 387.—Original.

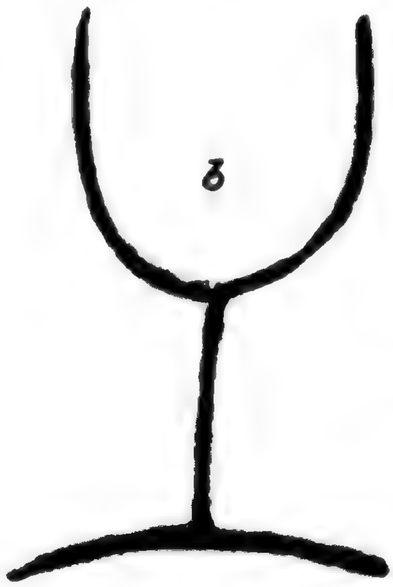

FIG. 388.
Reproduction of 387.

Another feat of Mr. Bishop consisted in driving, blind-folded, a carriage through a busy thoroughfare, for about a mile, and finding an article that had been hidden by the committee, they accompanying him. He also found articles secreted in different parts of the theater, when giving his exhibitions. In such cases he always took the person along with him who did the hiding, which suggests a possibility of muscle-reading.

FIG. 389.—Original.

FIG. 390.
Reproduction of 389.

Another person giving public tests of mind-reading, is J. Randall Brown, of Minneapolis. From a newspaper account I take the follow-

ing: One of his earliest public tests was given at the Bijou theater, New York. An insulated copper wire was extended from the theater to the Fifth Ave. Hotel. Prof. Cromwell, at the latter place, placed the end of the wire against his forehead, and Brown did the same with the other end, on the stage of the theater. With his eyes blind-folded he then wrote down Prof. Cromwell's thoughts on a black-board. When Prof. Cromwell came over to the theater, he acknowledged the writing to be a correct record of his thought. Another test was given by means of a wire between Philadelphia and Wilmington, 28 miles, Brown at Philadelphia reading the thought of ex-Gov. Pollock at Wilmington. The telegraph test was first suggested and practiced at Yale college.

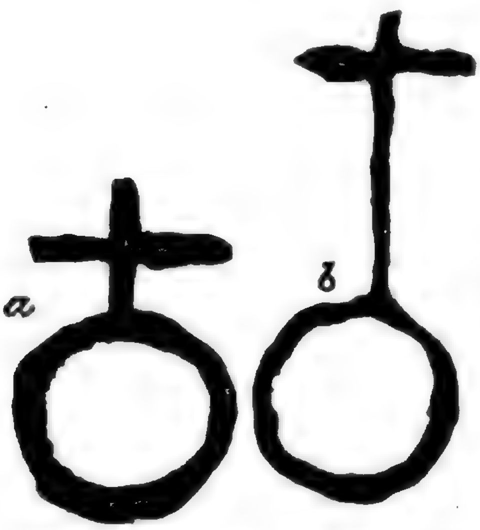

FIG. 391.—Original. FIG. 392. Reproduction of 391.

FIG. 393.

FIG. 393.—Original. When this was drawn, Miss Edwards almost directly said, "Are you thinking of the bottom of the sea, with shells and fishes?" and then, "Is it a snail or a fish?" Then she drew fig. 394.

FIG. 394.—Reproduction of 393.

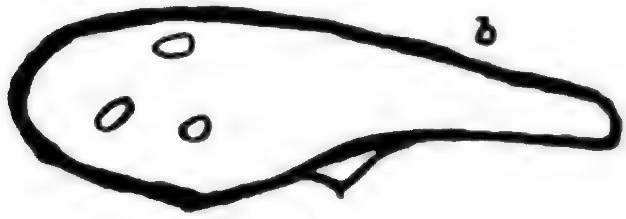

FIG. 394.

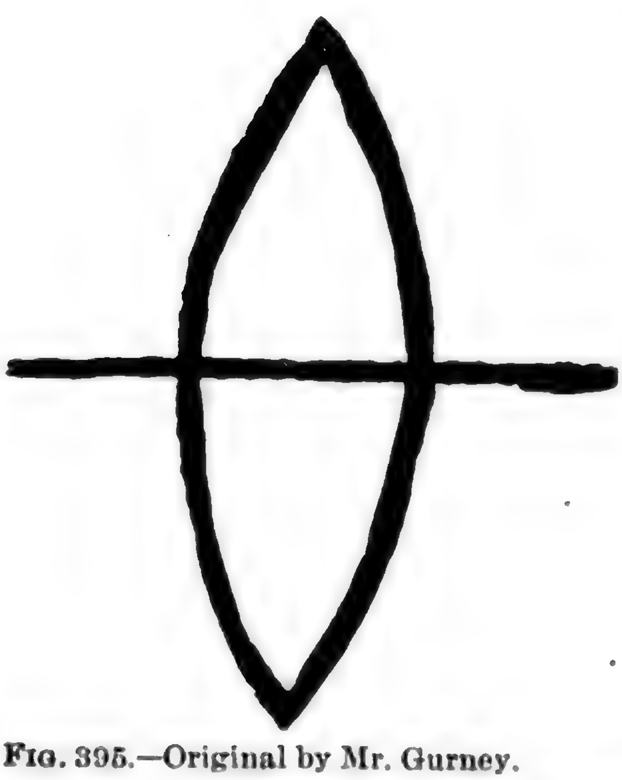

FIG. 395.—Original by Mr. Gurney. FIG. 396.—Reproduction of 395 by Miss Relph

The following newspaper statement gives a recent example of the conveyance of mental impressions to a person in the hypnotic state: "Paris, June 21, 1890. An elaborate series of hypnotic experiments

have just been concluded on Gabrielle Bompard, the alleged accomplice of Eyraud in the murder of M. Gouffe. The theory has been put forward that she was hypnotized by Eyraud, and made unconsciously to play her part in the tragedy by enticing Gouffe into her room, which he never left alive. It has been found that she is remarkably susceptible to hypnotic influences. While hypnotized she unhesitatingly obeyed every verbal command, and not only that, but with equal fidelity she obeyed the unuttered thoughts of the doctor when he was in another room far away from hers. He even went into another building, and there thought out a number of most unusual, extraordinary and difficult acts, every one of which she instantly performed. Dr. Bronardel, who conducted these experiments, declares her the most remarkable hypnotic subject he has ever met." This is pretty strong, but a hypnotic subject may be in a very superior condition to act the part of percipient.

FIG. 397. FIG. 398
397.—Original (Gurney).
398.—Reproduction of 397. (Miss Relph.)

The "Society for Psychological Research" reports the following:

Dr. Dusart had as a subject a hysterical girl of 14, who was very susceptible to hypnotism. He found he could influence her actions simply by his silent will. He made more than 100 experiments with uniform success. "On one occasion Dr. Dusart left without giving his usual order to the patient to sleep till a particular hour next morning. Remembering the omission, he gave the order mentally, when at a distance of 700 meters from the house. On arriving next morning at 7:30, he found the patient asleep and asked her the reason. She replied she was obeying his order. He said, 'You are wrong; I left without giving you any order.' 'True,' she said, 'but five minutes afterwards I clearly heard you tell me to sleep till eight o'clock.' Dr. Dusart then told the patient to sleep till she received the command to wake, and directed her parents to mark the exact time of her waking. At 2 p. m. he gave the order, mentally, at a distance of seven kilometres,[1] and found it had been punctually obeyed. This experiment was successfully repeated several times, at different hours."

The Literary Committee of the same society, in report of May 28, 1884, relate that a person, Mr. B, as an experiment, on the 22nd of March, at 10:30 p. m., secretly determined to impress a distant friend, Mr. A, whom he had previously been able to affect, but whom he had not lately seen, so that the friend should, at midnight, that is after Mr. B was asleep, see an apparition of Mr. B, and also receive a touch on the

[1] Four and one third miles.

head. Mr. A afterwards related that:—"On Saturday night, 22nd of March, 1884, I had a distinct impression that Mr. B was in my room. I distinctly saw him whilst widely awake. He came towards me and touched my head." The committee say they have received a report of another successful experiment of a similar kind.

The same report gives an authenticated case of an apparition which was seen by two persons at once.[1] Mr. James Weld, living near Southampton, in 1842, sent his youngest son Philip, to the Catholic college of St. Edmunds, near Ware, in Hertfordshire. April 16th, 1845, he was rowing on the river Ware, with one of the masters and some companions, and accidentally fell overboard and was drowned. At the same hour, as it afterward appeared, Mr. Weld and his daughter Katherine were walking out, and they both suddenly saw a distinct apparition of Philip, standing on the path on the opposite side of the turnpike road, between two other figures, one of which represented a youth dressed in a black robe. They started to walk towards the figures. Mr. Weld says, "Philip was looking with a smiling, happy expression of countenance, at the young man in a black robe who was shorter than himself. Suddenly they all seemed to me to have vanished; I saw nothing but a countryman whom I had before seen *through* the three figures, which gave me the impression that they were spirits." The figure in the black robe was afterwards identified as the effigy of St. Stanislaus Kostka, a Jesuit saint, to whom Philip was piously devoted, who is also reputed to be the especial advocate of drowned men. He was probably in the mind of the drowning youth at the time of his death. No further account is given of the third figure. The committee's theory of this case, is that of telepathic transfer of Philip's mental impressions to two percipients at once, both in rapport with the agent.

It was suggested above, that the human family may have lost something of the power of mind-reading. There appears certainly to be a faculty of mind-reading to a certain extent, amongst the lower animals. The subject is obscure and has not received sufficient investigation, but it appears tolerably certain that many animals have a silent method of transferring their ideas to each other. An anecdote is told of a certain horse and a dog who had formed a warm friendship for each other. They lived on a farm, and every morning the master of the animals drove the horse with a small market wagon into a neighboring town. The dog however, was never allowed to go. On the road between this farm and the town there lived another dog, who was of an exceedingly ugly and vicious disposition, and who never lost an opportunity to assail and annoy the horse every morning as he passed by. One day this annoyance was unusually irritating, and after the return of the horse, he and his dog

[1] See page 830. Chapter 74 was in type before I saw this account.

friend were observed to be in close communication for a long time. Next morning the dog started to accompany the wagon to town, and no orders nor threats of the farmer could keep him from following at a safe distance. When they reached the neighborhood of the ill-bred dog, he bounded past the wagon, and before the ugly beast could begin his customary attack, he assailed him in so vigorous a manner as to send him off howling with pain and terror. This done, he started back home of his own accord. The offending dog never troubled that horse again. Was there not some sort of thought transference from the horse to the dog, and purposive plan laid out by the latter? In what language was this confab carried on, if it was not simple impression?

A story from Wiltshire, England, is told in the Spectator. A lady visited a country place, which had a deer park, separated from the house by a lake 150 yards wide in the narrowest part. There were also two dogs, with which the visitor became well acquainted, a large collie, called Jasper, and his close friend, Sandie, a Skye terrier. One afternoon the visitor and the dogs started out for a walk. Coming to the lake the lady got into the boat and pushed off without considering the dogs. The big one swam after her, and when about half way over, they were startled by a wail from Sandie, who was running up and down the bank afraid to venture. Jasper looked appealingly into the lady's face and swam around the boat, but as she took no action he made for the shore, where there was a moment's silent pause, after which Jasper took a position half in and half out of the water, whereupon Sandie scrambled onto his back, his front paws resting on Jasper's neck, who then swam across the lake, and landed him safely in the deer park.

If the lower animals possess this power of thought transference, it is easy to see how such power would be lessened by an increase of ideas. We have seen that in hypnotism the aptitude of the percipient is greatly intensified by the simple process of temporarily reducing the number of ideas present to his consciousness, and in like manner the effectiveness of the agent depends on his power of excluding from his consciousness all ideas foreign to the one he wishes to transfer, and distracting from it. Amongst the lower animals the distractions from a variety of ideas are greatly reduced, and to the extent to which this reduction in number is carried, do the ideas remaining become instinctive, because the fewer they are the oftener they come into use, and the more firmly they are fixed. To the extent to which the ideas are instinctive, therefore, are they exclusive and persistent. This persistency is shown in such actions as that of the sphex, which went through the same maneuver of going down into her nest forty times in succession, when the sequence of her instinctive movements were disturbed and set back that often.

Whenever an instinct is disturbed by a distracting stimulation, so as to cause a hesitation or balancing to take place before a will is made up and action initiated, the process is reasoning. Obviously, therefore, as instinct is supplanted by an increase of the reasoning faculty, the conditions must become less favorable for the successful transference of mental impressions. Furthermore, the more complicated and detailed the idea to be conveyed, the less complete and satisfactory will be its transference. And this would lead to a supplementing of this mode of communication with signs addressed to one or more of the senses; in short, the adoption of language. In time, this method has, through its superior qualification for the conveyance of ideas, almost superseded the direct method. The latter may be said to be the language of instinct, while articulation, or other sign language, is the language of the intellect. Those animals which are in a middling position, whose actions are largely instinctive, and who yet possess a considerable degree of intelligence, it may be conjectured use both mediums of communication. Such are the great body of the mammals and birds.

CHAPTER LXXX.

LANGUAGE.

It has already been observed that the ordinary senses of animals are as sharp as those of men, and in many cases sharper. From what was said in last chapter, it even seems probable that they are endowed to a much greater extent than we are, with a telepathic sense. It might be asked, then, why, since all intelligence depends on the senses, are not the lower animals as intelligent as man? Intelligence arises from a conversion of the ethereal motions of the environment into ethereal motions in the brain. Consequently, other things equal, it is in proportion to the character and the amount of the environment, no two environments being the same or equal. A man living in a great city has a greater environment than one living alone on a small desolate island. So it is obvious that by means of *language* the environment of the individual is increased. The advantage of this is so great that it far more than offsets even a large deficiency of sensory acuteness. Language is a vast acquisition even to a savage, for it extends his environment so as to cover that of his neighbors for a great distance around, and he may be told what goes on in the next tribe at the same time that he sees what goes on in his own, and a traveler may bring him knowledge of far distant countries. This advantage is increased a thousand fold in the case of the civilized man, by means of writing and printing. The environment of a man who avails himself of the use of a great modern library, is practically the whole earth, and part of the sky.

Language arises from the expression in muscular motion of conditions in the brain. We have seen that such conditions are constantly and automatically giving rise to such muscular motions, as inevitably as a wind causes the flutter of a flag. As we know which way the wind blows when we see the flag flutter, so a savage, or even a wild beast, knows something of the "state of mind" of another when he sees his actions. Thus, all actions become signs of mental conditions, whether they are purposive or not. But it is only when signs are used for the purpose of conveying an idea of the state of the mind, that they properly become language. The associated activities of animals, their family, social and tribal relations, all arise from, and depend upon, the exchange of the indications of their mental states. The processes of such an exchange would therefore necessarily become a matter of evolution, and a subject of selection. The competition in such selection would be between the different motions which are forced upon the parts of the body by the internal state; the limbs, the head and neck, the eyes, the jaws and the voice. For many obvious reasons, or, in other words, from many obvious causes, the voice has been preferred among the birds and mammals, at least, and it has undergone more or less development in nearly all of them, as an instrument for the indication of internal states.

I think it can be shown that the purposive expression natural to ideation, as distinguished from mere emotion, is imitation. That is, it is natural to imitate the objective force which produced the idea. The auditory ideas are naturally expressed by the voice in imitating the sounds which originally produced the ideas. The sight ideas are naturally expressed by the limbs and body, especially the arms and hands, in producing an imitation of the visible objects from which they arose. Ideas of smell and taste are expressed by the muscles of the nose, face and lips, the imitation being in this case a reproduction of the facial movements, grimaces and expressions, caused by the stimulating objects in the first place. Original language would therefore be made up principally of imitative sounds, chiefly vocal, of gestures imitative of visible objects or movements, and of facial expressions imitative of those caused by subjective states of feeling. Accordingly we find children at first imitating the sounds they hear. A cow to them is a moo, a sheep is a baa, a rooster is a coo-coo-coo-a, a locomotive is a chu-chu, &c. The sound associated with an object is imitated to describe it, provided it is easily done. A little girl of my acquaintance just learning to talk, once, at the table, accidentally upset a cup of molasses. Her father in dipping it up again used, in a half chiding way, the exclamation of *goshee! goshee!* The term was at once innocently incorporated into the child's vocabulary, and thereafter when she wanted the toothsome sweet she always called for "goshee."

S. N. Rhoads, in American Naturalist for March, 1889, advances the opinion that the songs of birds are founded on imitations of other sounds. "The Mocking-bird, Catbird, Shrike and Jay, are studied and artistic imitators of their feathered associates, indicating the perfection to which bird language has developed as an art; but if we would seek examples of the primary instinctive exercise of the mimetic faculty, the notes of the Prairie Bluewing and Yellow Warbler, the Grasshopper warbler of Europe, the Yellow-wing and Savannah Sparrow, together with most of those of the ardeidæ, anatidæ, rallidæ, and some of the better known strigidæ and faliconidæ, afford a better illustration." Some of the above closely mimic the noises of the insects in their neighborhood. The yellow-breasted rail imitates the croak of the tree frog. The bittern and green heron imitate certain species of frogs, while the frog himself originally took his lesson from the rush of waters playing in and out of confined places. The long and short billed marsh wrens and the winter wren, sing in harmony with the noises of their aquatic surroundings, the bubbling of moving water, and the "prattle of woodland rivulets." "The same may be observed of the dipper, kingfisher, aquatic thrush, blue-yellow-back warbler, seaside finch, swamp sparrow, and others." The pteroptochos albicollis, a bird in Chili which stays about the bushes on the barren hills, is called the "Tapacolo," which means "cover your posteriors." Its tail stands up more than erect, tilting over toward the head. It is very sly and crafty. It has five different cries for different times of the year, "some of which are like the cooing of doves, others like the bubbling of water, and many defy all similes." (Darwin.)

Words which have been formed in imitation of sounds in the objective world are called onomatopoetic, literally to make names. Obviously only a part of a language can be onomatopoetic, since only a part of our environment gives us sensations of sound. Expressions which convey the ideas of the shapes, sizes, appearance and qualities of many things, their states of motion and rest, &c., can be produced by various gestures, and are naturally so produced. Even now in the most highly civilized communities, gestures are not entirely superseded by words, though they are ordinarily used as accompaniments and emphasizers. The western sheep ranchers educate a certain breed of shepherd dogs to obey signal gestures, which are, however, simple and so natural as to be easily taught to the intelligent dog. A beckon with the hand means *come*, a repelling motion *go*, a wave of the hand to the right or left means *move* in the direction indicated. A dog at the distance of half a mile or more will move as commanded by these signs, frequently stopping and looking back for further instructions. There are many cases on record of dogs, by natural gestures and physical demonstrations, soliciting the attention of their masters for a special purpose. In more

than one case the dog has by running forward, then stopping and looking back, whining or barking, or by tugging at the garments of his master, given him to understand that he wanted him to go with him to the relief or rescue of some one.

The Indian Sign Language, which is used by our western Indians over an area of nearly a million square miles, and by numerous tribes, is about as copious as most of the Indian spoken languages. It is indeed largely conventional, and many of the signs are arbitrary, but many of them are such obvious imitations of nature that an uninstructed person catches the meaning without difficulty.

The sign language has undergone growth and modification, and is doing so yet, and many of the signs have no doubt received the same sort of alteration that vocal words and written characters have; that is, there have been short cuts and simplifications made, by which the imitation of nature, which characterizes the original or root sign, has become obscured; just as our letters have lost their resemblance to the objects of which they were originally pictures.

The sign language has been in use from time immemorial. The Indians that attempt to account for its origin, think it was a gift from God, just as some civilized people yet regard written language. The Sioux Chief, "Iron Hawk," said to Capt. Clark that while God gave to the whites the power to read and write, he gave to the Indians the power to talk with their hands, and to make distant signals with the mirror, blanket and pony. The deaf-mutes in some of our schools for that class, are taught a sign language very similar to that of the Indians, and in many cases the signs are exactly the same. Of course the deaf-mute Indians, of whom there are a few, use the sign language exclusively. The sort of language we use is purely a matter of education with us. The child imitates his parents, and will learn the language they use, whether it be Russian, English, or Hottentot; or, if they are deaf and dumb, it will learn their sign language. Capt. Clark says: "I have seen the little three-years-old child of a deaf-mute Indian, hold up its tiny hands and carry on a conversation (without any attempt at vocal speech) which would have done credit to any child of that age." The children of Dr. Kitto, a deaf-mute, made signs *to him* (but not to others) before they were able to talk. Laura Bridgeman, the famous *deaf*-mute and *blind* girl educated by Dr. Howe, talked in her sleep with her fingers, and frequently talked *to herself* when awake, probably unconsciously.

Gesture signs are doubtless as old as vocal signs. The emotional movements are as old as emotional cries. The expressions of the horse with his ears, his neck, his nostrils, and his feet, are as old as his whinny and his neigh; and the dog indicated his mental state by the

movements and pose of his tail and limbs, as early as by his bark and whine. When expressive signs are used by a dog, or other intelligent animal, they are seldom exclusively vocal. It is the same when the expressions first become purposive. The vocal speech of the savages is poor, and was still more so in the beginning, and the necessity they were under to supplement and illustrate it by gesture speech, is not easily appreciated by those accustomed only to a complete vocal language. Clark expresses the opinion that in the earliest stages of purposive language, gestures were in greater requisition than articulate sounds. The final triumph and "survival" of the latter, however, indicates their title to be called the "fittest" in the long run. The sign language has become, like the vocal languages, largely metaphorical, because advanced ideas are not expressible without the help of metaphor. The following description of some of the Indian signs I take from Capt. Clark's "Indian Sign Language:"

Grass: Hold arms straight down in front of body, turn the backs of the hands down, and allow the fingers and thumbs well separated to point upward like spears of grass.

Trees: Same as for grass, except that the hands are held as high as the shoulder. For *one* tree, after making the sign for trees, hold up index of right hand.

Grow: With the right hand near the ground, back down, point upward with index, rest of the hand being closed, then raise the hand in slight jerks.

Mule: Hold the hands on each side of the head, palms in front, then throw the hands back and forth by twisting the wrist. Deaf mutes use the same sign.

Horse: Hold the left hand on edge, breast-high, pointing outward, then place right index and second fingers astride of left index.

Ride: With hands in position for horse, make vertical motion to imitate the canter or lope.

Dismount: Make sign for horse, then lift right hand, carry to right and lower it; repeat for more than one.

Water: Make sign as if drinking out of the right hand, tipping it toward the mouth like a cup.

Fish: Make sign for water, then with right hand on edge, waist-high, move it forward with waving motion.

Bird: Hold hands breast-high, palms outward, then flap them forward and downward, slowly or rapidly, according to the bird represented.

Fire: Hold right hand down in front, palm up, with first three finger nails pressed against the thumb, then snap the fingers upward, raising hand a little, repeating a few times.

Parturition: Hand is held open with palm inward, close to the body in front, then moved downward and outward on a curve.

Female: Make motion of combing hair on each side, with fingers made into a comb.

Male: Right hand, back up, is held in front of body, index pointing forward and upward, rest of hand closed.

Daughter: Sign for parturition and female.

Son: Sign for parturition and male.

Day: Hold open hands, breast-high, in front, four inches apart, pointing to front, backs up. Then with each hand describe a sweeping curve to right and left simultaneously, gradually turning the hands over and bringing them nearly to starting place, palms up.

Cloud: Hold the open hands in front, and higher than the head, backs up, edges touching, then sweep the hands apart to right and left, each describing about one-fourth of a circle, ending a little below the level of the shoulders. Often one hand only is used.

Heart: The edge of the right hand, with index finger and thumb pointing downward, and back up, is pressed against the region of the heart.

Sun: A circle is made by index and thumb of right hand but not closed by an inch. Move hand in a nearly vertical orbit from east to west. Time of day is indicated by thrusting hand as above, toward a position of the sun on such orbit.

Winter: Close the hands and hold them a little apart, in front of the neck, fore. rms

nearly vertical, then give the hands a shivering motion. This is also a sign for *year*. The same sign, with the addition of drawing in the shoulders and shivering the arms, stands for *cold*.

Exterminated or wiped out: Hold left hand palm up, then draw the right hand palm down over it from left to right, and passing some inches beyond.

Bald: Touch the hair of the head, then make sign for wiped out.

To Hide: Hold left hand in front of left breast, back up; then pass the right hand, back up, under and a little beyond the left.

Die: The conception of this sign is going under. The left hand is held in front on edge, back out, and the right closed, except the index, is passed under it close, so as to rub.

Perhaps, Doubt, &c., are conceived of as two hearts, and signs represent that idea.

Lie: Conception is of two tongues, or a forked tongue. The index and second finger of right hand are spread apart, the rest of the hand closed, then hand is moved past the mouth towards the left, and then downward a little. Also used for mistake.

Think, is conceived of a something drawn from the heart; the right hand closed, except index, is moved horizontally from the heart to the front.

Good, is something level with the heart, and sign expresses that idea.

Generous: Signs are made for heart, and for good or big.

Excite, is conceived of as a heart in a flutter. Sign for heart, then with hand and fingers all pointing up, make tremulous, waving motion.

Sad, is heart laid on the ground. Make sign for heart, then sweep the hand from this position to right and downwards, turning up the palm and partly compressing the hand.

Mean: Signs are made for *heart* and *small*.

Glad, is daylight in the heart, and the signs are for heart and day.

Mean, Selfish, &c., are expressed by compressed heart; signs are for *heart* and *small*.

Gloomy: Make sign for clouds, then lower the hands near to the head, the conception being that clouds press down upon one; much used to express despondency.

Crazy or foolish, is brain in a whirl, and sign represents that idea.

Bad, is something suddenly thrown away. Closed hands are held up and suddenly opened and thrown outward with repelling gesture. A little variation from this expresses *Abandoned*.

Ashamed, is expressed by gestures representing the drawing of the blanket over the face. Open hands, backs outward, are held before the face, then made to pass each other partly by twisting the wrists.

Moon: Make sign for *night* and for *sun*.

Month: Make sign for *moon* and for *die*. The moon dies. Sometimes the sign for *wiped out* is used instead of die.

Thunder: Make sign for *bird* and for *fire*.

Hunger: Cuts one in two. The edge of open right hand, back down, is pressed against the stomach, then drawn back and forth to represent sawing.

In the foregoing I have abbreviated the directions to save room. In practice the minute observance of details is of the same value as correct spelling in writing. Nothing can exceed the beauty of some of the metaphors employed, nor the grace with which the wild red men execute the gestures as I have seen them do. Capt. Clark has performed an exceedingly valuable work in preserving what will soon be a dead language.

The sign language, like vocal languages in their infancy, endeavors to imitate the object to be represented as far as practicable, and is both natural and ingenious in seizing upon some obvious characteristic in the thing itself or in our relationship to it; as, for example, in the signs for "mule" and "horse" respectively, and in those for bird, fire, rain, snake, snow, water, fish, &c. When the direct imitation of the object is no longer possible, resort is had to metaphor as in all vocal languages. Thus, *gladness* is sunshine in the heart, because sunshine produces gladness in the heart. A bad thing is something we suddenly hurl from us. Lowering clouds produce in us a sense of gloominess, hence clouds

pressing down, form an appropriate metaphor to express such feeling, however produced. *Perhaps*, or *doubt*, is having two hearts. The Aztecs use the same conceit in their verbal language; *ome* signifying "two" is combined with *yolli* "heart," forming the verb *omeyolloa* "to doubt." The sign language exhibits, as the vocal languages do, the paucity of original simple ideas, and the tendency in language construction to make the most of these by expanding and compounding. Capt. Clark gives the signs for about 850 expressions; but of these about 400 only are simple expressions, or *roots* as they might be called, the rest being compounds. Thus the sign for night is simple, and so is that for sun; but the conception of *moon* is that of a sun shining at night, and the gesture expression is a compound of *night* and *sun*; just as the German for glove is *hand-shoe* and for thimble is *finger-hat*.

Sign language is to be considered as picture writing in the air, and from it to picture writing is a short and obvious step. The first writing is always picture writing. Whether in the old world or the new, in Egypt or in Mexico, or among the savage redskins, the original conception of writing is a representation of the thing itself as exactly as possible. The idea of substituting symbols or arbitrary characters to take the place of these pictures, probably did not occur to the Egyptians until picture writing had been in use for thousands of years. But still the Egyptians had accomplished this and invented an alphabet at least as early as the 5th dynasty, say 4,250 years ago. A document on papyrus written at this period is still in existence. From this ancient alphabet the Phenicians derived theirs, and gave it to the Greeks, and from them it passed to all Europe. With the Egyptians, alphabetic writing did not supersede the pictures. The hieroglyphics continued to be used and studied by the privileged classes, as scholars now study a dead language that has become sacred.

The hieroglyphic writing contained direct representations of things as far as possible. The picture of the sun's disc meant the sun, the crescent, the moon; a male and female figures signified man and woman when separate, but when drawn together meant mankind. The Egyptians were under the same necessity as our Indians to resort to trope and metaphor to assist their expression of ideas of which no picture could be made. Thus, *heaven* and a *star* stood for *night*; a leg in a trap for *deceit*; a *pen* and inkstand for *writing*, and to *write* as well as a *scribe*; a man breaking his own head with an ax or a club meant the *wicked*, suicide being considered the most wicked act possible. Again, the *sun* represented a *day*, the *moon* a night; a youth with his finger to his mouth, a *child*; a man armed with bow and quiver, a *soldier*; a man pouring out a libation from a vase, or (later) merely the vase itself, a *priest*. The ground plan of a house, instead of a full picture, became

the sign for house. An egg signified a *child* or *son*; a *face* meant *before*; the front half of a lion was used to signify the *beginning*, and his latter end (hind-quarters and tail) meant the *end*. (Rawlinson.) The pictures of things gradually degenerated from true representations to mere conventional symbols. Later, these symbols, or degenerated pictures, became letters, each symbol standing for the first *sound* uttered in pronouncing its name. The Egyptian names of the letters would naturally be the same as the objects the pictures were made to represent in the first place. But when the Phenicians took the Egyptian alphabet, they gave the letters new names drawn from their own language, much as our nursery books rename them for the children's benefit, as A stands for apple, B stands for berry, C stands for cow. &c. In the Phenician, A stands for aleph (bull), B for beth (tent), G for gimel (camel), D for daleth (door), &c. By renaming them thus, the connection between the letter considered as a picture, and its name, was lost. The letter A never resembled a bull, nor B a tent. The Phenician *mem* was the new name for *M. Mem* means *water*. The Egyptian name was *mulak*, an *owl*, and originally was a picture of an owl; but all the bird disappeared in the course of time, except its two ears, represented by the two upright points of the letter, and the beak, shown in the middle downward point.[1]

The course of the evolution of writing has imitated more or less closely the evolution of speech. Writing is, in fact, a sign language, an attempt to reduce *all* the expressions of the brain to visible signs, while spoken language is an attempt to reduce them all to audible signs. Originally, the expressions are mixed audible and visible, the latter being a species of writing in the air (gestures). In the development of spoken language we may first attribute the ground-work or basis to the principles of onomatopœia and the imitation of natural sounds, including our own automatic interjectional expressions, &c. Next, there would be added words expressive of action, which words would be new adaptions of those already in use.

Language is the expression of conditions produced in the brain by external stimulations. It began at a time in the history of the race when mental conditions were of the most simple and rudimentary kind; before involved, general, or abstract ideas could have been developed. Words that express such ideas, therefore, could not possibly have been among the first to come into use.

Philologists attribute the origin of the great body of words to a comparatively very small number of roots. This is undoubtedly correct. But in trying to ascertain which words are roots, it is extremely easy to make a mistake and get the cart before the horse. As ideas grow from

[1] Isaac Taylor, "The Alphabet."

specific to abstract and general, language must have taken the same course. Thus, infants of all nations have named their parents Pa and Ma, and such words have been adopted by the elders. This is undoubtedly the course of nature. Words must at first have been involuntary articulations, and without definite signification, until by their accidental or natural association with objects, they became attached to them in the mind. There is in the Aryan stock a root *pa*, which signifies to nourish; and from this root are said to be derived such words as pap, pa, papa, parent, father; Latin, pater; Sanscrit, pitar, &c. This statement would imply that men first got the abstract idea of nourishing and being nourished, and then with great discrimination applied the word they attached to that idea, to objects which they found concerned in the business of nourishing. In the history of language we do come to a period when this sort of thing is done; but it certainly could not have been done at the very first. Thus, *parent* may have come from *pa*, but the first signification of pa could not have been *to nourish* or to bring forth; but the word simply attached itself to a visible, tangible object, the mother or father. The idea of that object being a nourisher would occur later, and when it did occur, the idea of nourishing in general (or begetting) would be associated with the first one that had been named, and his name would be applied thenceforward to the idea.

Pa and ma are the words which, with their derivatives and corruptions, stand for father and mother in most of the languages of the earth. Amongst the different African languages the following are used for father: papa, paba, baba, pa, fa, fafe, fafa, ba, da, dadye, wawa, dada, nda, ada, bawa, aba, mba, babi, tada, oda, abba. For mother the following are used: ni, ne, nana, na, mana, kara, ba, nde, nga, ma, noe, de, iya, yeye, ye, nene, ayo, nna, mo, meya, nno, onyi, onya, ya, aye, am, bina, mama, mma, ondsunei, omsion, aai, nya, inya, kunyun, ua, yuma, inna, ina, ene, ama, omo, omma. Among the non-Aryan nations of Asia, there is again the same remarkable agreement. In Turkish father is *baba*, and so it is in parts of India, and in Java. In Thibet *dhada* is father, and *ma* is mother. Other words used for father in different parts of Asia are, *mama, ama, bapa, pha, aba, apa, bubai, abo, appa, amma, ma*, &c. In Chinese it is *fu*. Words for mother are, *ma, ana, deda, eme, ibu, ama, ami, anu, yu, enga, appe, avve, amo*, &c. In Chinese it is *mu*.

In almost all languages the words for father, mother, baby, &c., are clearly derived from the sounds which babies automatically speak when they first begin to articulate.[1] Lubbock's idea that pa "to nourish" is a derivative of pa the noun, is certainly more probable than the contrary view. Dr. Noah Webster attributed the adoption of the words for father and mother so nearly alike, among remote and unrelated nations, to the fact that such words are simply the most easy, and therefore the earliest automatic articulations of children; and he says that if all such words were lost they would speedily be replaced without any communication or convention for that purpose.

Savages have few or no general terms. Thus it is said the Brazilian tribes had "separate names for different parts of the body, and for all

[1] See Lubbock Origin of Civilization.

the different animals and plants with which they were acquainted, but were entirely deficient in such terms as 'color, tone, sex, genus, spirit,' &c. The Choctaw language has names for the black oak, white oak and red oak, but none for *oak*; still less for *tree*. The Tasmanians, again, had no general term for *tree*, though they had names for each peculiar kind; nor could they express qualities, such as hard, soft, warm, cold, long, short, round," &c. (Lubbock.)

There are tribes of Mongolian or Turanian origin which have no word for *river*, though they have names for every river and rivulet they are acquainted with; they have no word for *finger*, but names for the thumb, ring-finger, &c. No word for *berry*, but many names for cranberry, strawberry, blueberry; no word for *tree*, but names for birch, fir, ash, and other trees. In Finnish the name given to the *thumb* finally became the general name for finger, and the name of a certain kind of berry, the waterberry (empetrum nigrum), became the general name for *berry*. (M. Müller.)

The gesture language of our western Indians has no sign for the general idea *fruit*, although there are signs for berries of different sorts, apples, cherries, &c. There is no sign for "animal," nor for "game," nor for "meat," though there are signs for specific kinds of them all. There is no sign for *rich*, but to say that a person "has many ponies," conveys the idea that he is rich.

These facts go to prove, that, as observed above, there are at first no abstract ideas, but that such ideas arise from the superposition upon one another, and the final condensation of a large number of concrete or specific ideas; the quality common to them all not appearing till this synthetic process is accomplished. It is certainly impossible that terms conveying abstract ideas could have been the first to come into existence or to sustain the relationship of primary roots. Inability to comprehend abstract qualities includes inability to count or perform mathematical operations. Many savage tribes cannot count more than two. Those who are able to count a considerable number, do so at first by the help of some objective bodies. Almost universally the fingers and toes stand for numerals at first. Some of the Australian tribes have but two numerals. On the Lower Murray, *ryup* is one; *politi*, two; *murnangin*, hand; *ryup murnangin*, one hand, is five; *politi murnangin*, two hands, means ten. In Labrador, *tallek*, a hand, means also five, and the term for twenty means hands and feet together.

"The Zamuca and Muysca Indians have a cumbrous but very interesting system of numeration. For five they say 'hand finished;' for six, 'one of the other hand,' that is to say, take a finger of the other hand; for ten they say 'two hands finished,' or sometimes more simply 'quicha,' that is, 'foot.' Eleven is foot-one; twelve, foot-two; thir-

teen, foot-three, and so on; twenty is feet finished, or in other cases 'man,' because a man has ten fingers and ten toes, thus making twenty. Among the Jaruroes the word for forty is 'noenipume' i. e., two men, from noeni, two, and canipume, men."

The natives of Guiana for five say "my one hand," and for ten my two hands. From ten to twenty they use the toes. Twenty is "one man." Forty-five is expressed by saying "two men and one hand." The Caribs for ten use words meaning the fingers of both hands, and for twenty the words meant fingers and toes. The Abipones for four use words meaning the "fingers of an Emu." (It has four toes.) For five, ten and twenty, they use words meaning fingers and toes. The Malays and Polynesians use for five, a word which in one of the languages means hand. For six, the Zulus say "take the thumb."

According to Humboldt, the word pencha, in Persian, is hand, and pendji is five. The Sanskrit for five is *pancan*, derived from *panc*, which means spread out, as the digits of the hand. Five in Greek is *pente*; in Armoric, a Celtic dialect, it is *pemp*; Welsh, *pump*; German, *fünf*; Saxon, *fif*. So it appears our *five* means *hand*. The word "digits," which we apply to the numerals, means *fingers*, and the characters I, II, III, are pictures of fingers held up; V is the whole hand raised, the left prong representing the thumb, and the right the other four fingers. The two hands, or ten, are represented by VV or X, and IV and VI are pictures of a hand with a finger subtracted or added. The Sanskrit character for five probably represented a hand also. The surmise of Lubbock that the decimal system of numerals arose from the fact that we have ten fingers, is quite probable. He says either 8 or 12 would have been more convenient than 10, since 8 can be quartered by whole numbers, and 12 can be divided by 2, 3, 4 and 6.

There cannot be words for which there are no ideas, although the reverse may in some degree be true. Inchoate or partially developed ideas, may remain without expression and dumb if no necessity for their expression arises. For example, in the Hawaian dialect "black and blue and dark green are not distinguished, nor bright yellow and white, nor brown and red. This arises from no obtuseness of sense, for the slightest variation of tint is immediately detected by the people, but from sluggishness of mind. In the same way the Hawaians are said to have but one term for love, friendship, gratitude, benevolence, esteem, &c., which they call indiscriminately *aloha*, though the same people distinguish in their dictionary between *aneane*, a gentle breeze; *matani*, wind; *puhi*, blowing or puffing with the mouth; and *hano*, blowing through the nose, asthma." (M. Müller.) We thus see that words do not appear till ideas require them. And no matter what the brain capacity, ideas do not spring into existence till the brain is acted

upon by the environment. The social life of the Hawaians rendered the distinction between love and friendship unnecessary, while the difference between a breeze and a wind, as navigators they could not ignore. As rapidly, therefore, as the environment creates ideas in the brain, will new words be coined, or old ones be newly adapted or transferred from another language. But since ideas are at first of objects audible, visible or tangible, we may be sure that the first words were nouns. There are many obvious qualities, relationships and actions of things which appear to us simultaneously with the things themselves. Thus, when a savage sees a wild horse he cannot help seeing that he runs, and in seeing the moon he will also see that it is round and that it is bright. If he undertakes the domestication of the horse, he will need and soon invent a name for him, and that name will be, or soon become, the name not only of the animal but his action, too. But he will probably get along for some time without any name for the moon, and still longer without a name for the abstract qualities of roundness and brightness. Suppose [1] *kar*, or *har*, to be the word adopted by our savage for the name of his horse. As running is the most characteristic thing about a horse, as soon as attention is directed to similar action in other objects, the same name will be applied to it. Of any animal that runs, it will be said it does like the *kar*, it *kars*. In Latin this is cur (curro). The word will thus be extended to apply where movement renders it appropriate. A body of water in motion is now called a *current*, and a wind is a *current* of air. After awhile money passing from hand to hand is currency, or *current* money, and we finally rise to such expressions as *current* opinions, *current* topics, the *current* of time, *current* events. In the meantime a wheeled vehicle is invented, and as it is intended to go like a horse, it is called *currus*, from which we get *curricle* and *car*, also *curriculum*, a race course, and later a course of study in college. The word *course* itself is from the same root, and means *to run, to pursue*; and as a noun it has been applied to a great number of things—as a track or path; the movement of anything, as a ship, an animal, and the earth in its orbit. We say *course* of conduct, *course* of descent, of an argument, of duty, of law, of medicine. We say *course* of stone, course of brick, the courses of a dinner. Of anything which should run after another, we say it will follow of *course*. From the same root we get *courier*, one who runs to carry the news, &c. Next, as men's ideas increased, they were expressed by new applications of such words as they possessed as long as that process would answer. Thus, we get *concourse*, a running together, hence a meeting, a crowd; *discourse*, a running about (in speech); *discoursive*, applied to reasoning; and *discursive*, moving about. Then we have ex-current, excur-

[1] This is an Aryan root, meaning to run.

sion and excursus, all implying running out; and *incur*, to run against; incursion, a running into; occur, occurrence, &c., running up to; and recur, recurrent, &c., running back. Now all these derivatives, and many more, have been built upon that Aryan root *kar*, and whenever the idea of running in any direction is sought to be expressed, some new application is apt to be made of this root or some of its derivatives. I have assumed *kar* as an original name of the horse rather for the sake of an illustration than as a statement of a known fact, although it appears not at all improbable. The Teutonic form of *kar* is *har* and *hor*[1], from which we have Anglo-Saxon *hors*, Middle English *hors*, Icelandic *hors* and *hross*, Dutch *ros*, German *ross*, Middle High German *ros* and *ors*, Old High German *hros*, all meaning *horse*. Anglo-Saxon *horse* is swift, Middle High German *rosch*, swift. Another form of the Aryan root is *kal*. In Sanskrit, *kal* is to drive; *char* or *chal*, to move. In Greek, *keles* is a race-horse, or riding-horse; *kello*, to run swiftly or to drive; *bou-kolos*, a cattle driver. From the same is the Latin *curro*, to run; *celer*, swift; Breton *karr*, a chariot; Irish *carr*, a cart; Breton and Welsh *gar*, the shank of the leg; English *bucolic*, pole, monopoly, current, celerity, car, carol, garter, garotte, horse, calash, rush. There is another Aryan root *ak* (Teutonic form *ah*), to pierce, to be sharp, to be *quick*. From this root is derived the Sanskrit name for horse, *acva*; also the Greek *ippos*, horse; and *akros*, pointed, extreme; *akone*, whetstone; *akon*, javelin; *akme*, the edge; Latin *acus*, a needle; *acer*, sharp; *acuere*, to sharpen; *acies*, edge; EQUUS, horse; Gothic *ahana*, spear of grain, &c.; English *acacia*, *acme*, aconite, acrobat, hone, *hippopotamus*, acid, acute, ague, *aglet*, EQUINE, *eager*, *edge*, *egg*, *ear*, *axe*. (Skeat.) It is reasonably certain that the Aryans were acquainted with the *horse*, and had words both from *kar* and from *ak*, to *run* and to be *quick*, before their dispersion. They had two names for the horse, the Northwestern division retaining *har*, which, I conjecture, was the original name, and the Asiatic and Southern divisions taking up *akva*. The Greeks kept both names.

The cow is an animal that was known to the Aryans before their dispersion took place, and the name is found in the Aryan languages generally. In Saxon, cow is *cu*; Dutch, *koe*; German, *kuh*; Swedish, *ko*; Danish, *koe*; Latin, *ceva*; Hindoo, *gaj* or *gou*; Persian, *koh*; Pahlavi, *gao*; Sanscrit, *go* is cow and *gau* an ox. In Greek, *gaulos* is a milk-pail. These words are said to be derived from the Aryan root *gu*, meaning to low or bellow. In Sanscrit, *gu* means to sound; *godama* is a cowherd, and *gopa* means a king. According to Max Miller, the "king" was first the head of the cow-pen or owner of the herd, then chief of the tribe. *Goshtha*, at first the cow-pen, came also to mean an assembly.

[1] Skeat's Etymological Dictionary.

Gotra meant the herd and afterwards a family, tribe or race, &c. Now it is to be observed here that the word for *bellow* is the same as that for cow. It is not described as the bellowing animal, but simply as the "*bellow.*" May not this word be an original one and founded upon onomatopœia?

We see how in the coinage of new terms the tendency has been to saddle upon nouns the function of verbs and other parts of speech. Lately the nouns telegraph, telephone, &c., were introduced, and immediately were followed by the verbs *to* telegraph, *to* telephone, *to* wire, &c. *To* telescope a train is a late performance, both in mechanics and language. Hundreds of words do duty both as nouns and verbs, &c. In England a coachman is often called a *whip*, so that "see the whip whip the horse with a whip" would be correct English. We "stand the stand in the hall," chant a chant, bolt with a bolt, bribe with a bribe, answer with an answer, plow with a plow, &c. There are hundreds of words that perform these double duties. We distinguish in such cases between the verb and noun by the help of other words; but in the beginning of language this was not done, the distinction being left to inference, as when we say "rats" to a rat terrier, leaving the dog to fill up the sentence. When the ancient herdsman of few words addressed his cow-boy with the syllable *gu*, it would mean a whole sentence according to circumstances; as "I see the cows;" "the cows bawl;" "the cows have come;" "go milk the cows;" "the cows are in the turnip patch;" "drive the cows to pasture." From the single word the boy could figure out the rest.

Max Müller observes that the Chinese *ta* may be rendered *great*, *greatness* or *greatly*; *li* is *a* plow, *to* plow, or an *ox*, the plower. The Egyptian *anh* is life, living, or lively.

Thus, no doubt, after names had been obtained for a few sensible objects, the same names would become adjectives and verbs, expressive of the most obvious qualities or actions characteristic of the objects.

As to the origin of these first or root words, as before remarked, a large number are imitations of sounds occurring in connection with the object. But the words thus adopted are to a great extent the result of intelligent purpose; that is, the sound arouses conscious sensibility and suggests imitation, although no doubt the greatest number of original words, those which became roots, were involuntary, and so far the result of whim, freak or caprice as to be in effect accidental. I once knew a little boy who was born deaf without any other defect physical or mental. As soon as he became old enough to run about, he began to articulate. No doubt he meant something by his words, but so far as I know no one took pains to find out what. At the age of four or five he had adopted the word *pug-ge-dy* which he repeated with great

volubility whenever he met someone he knew. He was sent to school and became well educated. Pug-ge-dy was the easiest articulation in this case for organs already formed for articulation, and no doubt expressed some state of the boy's mimd. It illustrates what took place at the beginning of language; such vocal organs as were then possessed being set in motion by conditions of the brain and uttering the cries they were fitted for.

It is said of certain villagers in the desert parts of Africa, that often all the able bodied adults are obliged to be away from home for weeks at a time, on long expeditions, leaving the children in the care of a few infirm old folks. These youngsters, left largely to their own devices, construct language in their own way. "The more voluble condescend to the *less precocious*, and thus from this infant Babel proceeds a dialect of a host of mongrel words and phrases, joined together without rule, and in the course of one generation the entire character of the language is changed." (Müller). This "condescension" to the "less precocious" is significant of the absence of plan or premeditation, and the adoption of the haphazard articulation of infants likely to occur in the earliest formation of language, among people whose mental condition never got much beyond that of infancy. Occasionally children, from bashfulness or some unaccountable whim, refuse to learn their mother tongue and invent a speech of their own. Horatio Hale, in an address before the "American Association," discusses this subject and gives some examples [1]. In one case near Boston, twin boys adopted a language of their own, refusing to learn their mother tongue till they were sent to school at the age of six or seven. For a week they were mum, watching and listening to the rest; they then began to talk English and gradually forgot their own language. Another case described in the Monthly Journal of Psychological Medicine in 1868, is that of a little girl at Albany, N. Y., who at two years of age began to talk in a language of her own, and constructed a considerable vocabulary which was afterwards acquired by a brother 18 months younger than herself, and they used it freely between themselves, though the boy used some English words to converse with his parents.

Lubbock observes: "Many names of animals, such as cuckoo, crow, peewit, &c., are evidently derived from the sounds made by those birds. Every one admits that such words as bang, crack, purr, whizz, hum, etc., have arisen from the attempt to represent sounds characteristic of the object it is intended to designate. Take again the inarticulate human sounds, sob, sigh, moan, groan, laugh, cough, weep, whoop, shriek, yawn; or of animals, as cackle, chuckle, gobble, quack, twitter, chirp, coo, hoot, caw, croak, chatter, neigh, whinney, mew, purr, bark, yelp, roar, bellow; the collision of hard bodies: clap, rap, tap, knap, snap, trap, flap, slap, crack, smack, whack, thwack, pat, bat, batter, beat, butt; and again, clash, flash, plash, splash, smash, dash, crash, bang, clang, twang, ring, ding, din, bump, thump, plump, boom, hum, drum, hiss, rustle, bustle, whistle, whisper, murmur, babble, &c. So also sounds denoting certain motions and actions: whirr, whizz, puff, frizz, fly, flit, flow, flutter, patter, clatter, crackle, rattle, bubble, guggle, dabble

[1] See Popular Science Monthly.

grapple, draggle, rush, shoot, shot, shut, &c. Many words for cutting and the objects cut or used for cutting, &c., are obviously of similar origin. Thus we have the sound sh—r with each of the vowels; share, a part cut off; shear, an instrument for cutting; shire, a division of a country; shore, the division between land and sea, or as we use it in Kent, between two fields; a shower, a number of separate particles; again scissors, scythe, shread, scrape, shard, scale, shale, shell, shield, skull, shoist, shatter, scatter, scar, scoop, score, scrape, scratch, scum, scour, scurf, surf, scuttle, sect, shape, sharp, share, shave, sheaf, shed, shoal, shred, split, splinter, splutter, &c."

The Tutuco (ctenomys brasiliensis) is a curious small gnawing animal with the habits of the mole. Its name Tutuco, is an imitation of the sound it makes while burrowing under ground. The Teru-tero (vanellus cayanus) which resembles the English peewit, is a South American bird (Patagonia and Buenos Ayres), named from the sound it makes. (Darwin.) The *Momot* is a bird, and the *Quagga* a quadruped, both named from the sounds they utter.

The sound of *st* seems to be a natural exclamation commanding silence or stillness, as in "*hist*" and "whist." Perhaps it is in imitation of the hiss of the serpent which challenges a halt. From stillness to *fixedness* is an easy transition, and at any rate we find a large number of words of Teutonic and classic origin, containing the sound *st* and implying the quality of fixedness; as stable (adj.), stall, (from which we get stable, the noun) stack, stab, staccato (Italian), staddle a staff, stage, stagger to *cease* to stand firm, stagnant and stagnate, staid, stain (a spot), stamp an imprint, hence the verb stamp; stand, stallion, stair, stake, stalk, stamen, stump, stupid, sturdy, stick, stem, stone, strong, and fifty more.

Where we cannot finally trace original words to obvious imitations of natural sounds, we can only account for them as whimsical, capricious or accidental. A whimsical word may be an imitation according to the fancy of one person, when another might see little or none in it. *Mar*, for example, is an Aryan root, meaning to grind. Now it is quite possible that the person first using that word might have done it through an impulse of some grinding sound, of which m-r-r was, in his fancy, some sort of expression.

So *tup*, to strike, may have been the whim of someone, an expression he would use to accompany the gestures by which he might attempt to convey the idea of a blow. Just as it is natural for a dog who wishes to convey an unusual idea to his master, to accompany his expressive movements with the voice in little, inarticulate whines and barks, so, no doubt, it was equally natural for man, possessed of the power of articulation, to accompany with articulations of some sort, his gesticulatory efforts to convey ideas. If he was trying to show in pantomime how one savage struck another, he might accompany the action by the monosyllable *tup*, for example, as likely as by any other. This is the Aryan root-word for *strike*. We find it in the Greek *tupto*, to strike; in the English *tup*, a *ram*; and *tup*, to *butt* as a ram.

But we are to consider that it is now out of the question to get down to the real beginning of language, especially to the real original root-words of the Aryan languages. The roots we find in these languages may be many removes from the original words. Passing from mouth to mouth without any standard of accuracy or purity, words could not possibly long remain the same. In the changes which the root-words of the Aryan tongues underwent before they became Aryan, and while they

still formed the scanty body of the jargon of the wild savages who were the ancestors of the Aryan race, it would be no wonder if many of them lost such traces of onomatopœia as they may have had in the beginning. Consider again the root *tup*, to strike; it is also written *stu*, *stup*, *stud* and *tud*. We have still another form, which was in use a few generations ago, then dropped, and now lately revived. It is certainly onomatopœic. It is the word *thud*, meaning the sound of a heavy, soft body falling on a hard surface; for example, as the reporter might state it, "the man fell from the seventh story to the pavement with a sickening *thud*." So might some such sound have reverberated through the cranium of an ancient savage, and imitated itself through his vocal organs as *tud*.

A larger number of abstract words than we might at first suppose, may have been suggested by natural sounds, since there is scarcely any sort of physical action which is not at some time or other accompanied by some sort of sound. But to whatever imitations of sounds, whether constant or occasional, or to what fancies, or temporary freaks, or sudden whims, language is indebted for its original stock of words, we can at this late day hardly feel sure of any, except such as are yet manifestly onomatopoetic.

The Aryan tongues are adapted to express the advanced ideas of civilized people, and therefore are as much beyond the savage languages they sprung from as civilization is beyond savagism. As ideas of things change, their names and the manner of speaking of them change. The gas which accumulates in wells sometimes, used to be called *choke-damp*. That significant name is now almost superseded by the equally significant *carbonic acid gas*. The first describes what it can do; the latter tells what it is, and could not have been applied till chemistry had found out the facts of its composition. We call our Earth "the Globe" about as often as anything else, but this name could never have been applied till men learned its true shape. As far back as civilized languages can be traced, we find proofs of this process of renaming so as to express the growing ideas of things.

Our word *moon* is traced to an Aryan root *ma*, to measure. Sanscrit for moon is mâs, for month it is masa; I measure is mâmi, a measuring stick is mâ-tram, which in Greek becomes *metron*, and in English is *meter*. In Greek, moon is *mene*, month is *men*. In Latin, month is *mensis*. In Gothic, moon is *mena*, and month is *menoth*. In Anglo-Saxon, moon is *mona*, and month is *monadh*. (M. Müller.) Thus, the moon is a measurer, and the time she (or rather *he*) measures is a month. But certainly no one will pretend that men refrained from giving a name to the moon until they had become familiar with its periodical movements, and had instituted festivals and observances timed by

them. This name superseded a hundred at least that the moon had borne before men knew or cared for it as a measurer. To a savage its function of lighting is vastly more obvious than that of measuring time. Our Indians called it the *night sun*. Again, we are informed that *thunder* is derived from the root *tan*, which means to *stretch*, and "expresses that tension of the air which gives rise to sound." (M. Müller.) In Sanscrit, thunder is *tanyu*, in Latin it is *tonitru*, from which our own word is easily derived. From *tan* also comes the Greek *tonos*, our *tone*, tone being produced from stretched strings. From the same *tan* comes the Latin *tendo*, to reach out; *tenuis*, thin; *tener*, tender, and our words *thin* and *tender*, the last meaning stretched out, and hence delicate. Now, no savage ever lived who first conceived of thunder as an air-stretcher. Lightning might early have been thought of as a *streak* (as we often speak of it even now), and the word *tan* used to express that sense as something like a string extended or stretched across the sky; and this would imply that thunder and lightning were not at first distinguished from one another. But it is easy to see that even in this to us rather obvious expression, there is too much generalization implied for an original term. The first names could not be general names, or names of classes of things. If some particular line or mark had been called a *tan* (a stretch or streak), this term would not, at first, through the comparison of such mark with another of a distinct kind, be also applied to it. We say *streak of lightning*, and this expression implies that we have compared lightning with a streak of something else, and it also implies that before it was possible to say *streak of lightning* we had possessed one idea of some streak, and another idea of lightning, and the third idea, arising from the union of the other two, did not occur till long afterwards.

Ovis, the Latin name for sheep, is also found in Greek, Sanscrit, Teutonic, Lithuanian, Slavonic and Celtic. It was therefore a common name in the original Aryan tongue before the dispersion. It is said to come from the root *aw*, to be pleased or satisfied. In Sanskrit, *av* is to please; Latin *avere*, to desire; *avarus*, greedy; *ovis*, pet animal, &c. Also *auris*, the ear, and *audire*, to hear. Gothic *awi*, is sheep, ewe; *awso*, the ear. In English, *æsthetic*, *audience*, *avarice*, *ave*, *uncle*, *ear*, *ewe*. (See Skeat.) But there is another word by which the same animal is designated; viz., in English, *sheep*; in Saxon it is *scep*; German, *schaf*; Dutch, *schaap*. These words are derived from the root *skap*, to cut (hence to castrate). In Polish, *skop*, and in Bohemian, *skope*, mean a wether or castrated ram. In Polish, *skopowina* is mutton; in Russian, *skopite* is to castrate. Italian for mutton is *castrato*. A later form of *skap* is *kap*, from which comes the Greek *koptein*, to cut; also the Latin, *capo*; Dutch, *kapoen*; Danish, *kapun*, and English, *capon*, all meaning a castrated rooster.

It is obvious that *sheep* is a later name for the animal than ovis. It occurs in only a portion of the Aryan tongues, which indicates that it came into use *after* the dispersion, and it was adopted after the introduction of castration. It is therefore not an original name; but neither is ovis, for it must have come into use after the domestication and petting of the sheep, and there must have been a name for the animal during the ages it ran wild.

Many root words, and probably most of them after having given rise to derivatives, have themselves become obsolete and lost. This is especially the case with imported words, derivatives often being imported while their primitives are left behind and forgotten.

In Sanscrit the word for cat is *marjara*, which is derived from the root *mrij*, to clean. So the name in Sanscrit means the animal which cleans itself. (Müller.) It is not possible that this was the original name for cat. Savages who probably had but small discrimination between cleanliness and dirtiness anyway, would not be likely to have postponed naming the cat till a general term for cleaning up had been invented. The fact is (I have no doubt) that the word *cat* is a far older word than *marjara*. It cannot be traced to any antecedent root, and is found in many languages. In Irish it is *cat*; French, *chat*; Dutch, *kat*; Danish, *kat*; Swedish, *katt*; German, *kater* or *katze*; Latin, *catus*; Spanish, *gato*; Polish, *kot*; Russian, *kots*; Welsh, *cath*. It also occurs in Turanian and Semitic languages. In Turkish it is *keti*; in Basque, *catua*, and in Arabic *kitta* or *kaita* is a male cat. It was doubtless a word before the Aryan was distinguished from the Semitic. We sometimes speak of the cat as a *mouser* in much the same way as the early Sanscrit people may have spoken of it as the animal that cleans itself—the *marjara*; but with us, *mouser* has not superseded *cat* as *marjara* appears to have done with them.

The term mouser is from *mouse*, and this is said to be from the *Aryan* root *mus*, to steal. Mouse in Dutch is *muis*; Icelandic, *mus*; Swede, *mus*; Russian, *muish*; Latin, *mus*; Greek, *mus*; Persian, *mush*. In Sanscrit *musha* means a rat, a mouse and a stealer; and *mush* is to steal. I fail to discover any way to prove that the term *mus* was used to signify *to steal* before it was used to signify a mouse. Men had experience of both thieves and mice before they possessed articulate language; and which got a name first must be left to conjecture. My guess would be that the mouse, or rather the *rat* (as intimated in the Sanscrit), first received the name, which came afterwards to be applied to the more abstract and involved conception of thief and stealing. The word *rat*, by the way, is perhaps a later name for an animal which was first called *mus*. There is an Aryan root *rad*, which means to scratch, and hence to peck and gnaw. *Rat* is supposed to be derived from that

root. Rat in Danish is *rotte*; Swedish, *ratta*; German, *ratte* and *ratz.* In Sanscrit, *rada* is a tooth; in Latin *rado* is to scratch, *rodo* to gnaw, *rostrum* a beak (to peck with), and in English we have also *rodent*, a gnawing animal. Of course in this instance it is possible *rad* may have first been the name of the animal and afterwards received its general signification; or it might be the animal was first called *mus* and afterwards renamed *rat* in recognition of its characteristic propensity for gnawing. After the terms *rad* and *mus* had come to receive a general signification, either would be a suitable name for the rat, and that one would gain the day which was on the whole the *fittest* and most appropriate.

Max Müller observes that in *ancient dialects* there was a superabundance of synonyms, and a "*struggle for life*" between them. He says any feature of a thing "that struck the observing mind as peculiarly characteristic could be made to furnish a new name. The sun might be called the bright, the warm, the golden, the preserver, the destroyer, the wolf, the lion, the heavenly eye, the father of light and life." He also makes the almost incredible statement that there have been counted no less than "5,744 words relating to the camel," (certainly not all in use at the same time). Such a redundancy of significant and poetical names could not occur in the beginning of language, but would prevail as soon as a moderate degree of civilization had been reached. Then a struggle for existence would take place between the different words applied to the same thing. This struggle goes on yet and always will. A great many words are constantly being coined and put upon probation. For example, we no longer hear of a "dandy;" he has become a "dude," he makes a "mash" instead of an impression; there is no longer a "groggery," but he may frequent a "saloon." The word "groggery," which has been overthrown by "saloon," was short lived, not having endured more than two generations. "Skedaddle" is a word which flickered during our civil war and then went out. The dictionary contains a surprising number of words which are either obsolete or almost so, but which were in common use a few generations ago. A great many words have been introduced by the "best writers and speakers" which never met with much encouragement. A large number of classical words have thus been introduced which were probably never assimilated, such as *algid*, cold; *alimonious*, nourishing; *allegiant*, loyal; *arride*, to laugh at; *conject*, to throw together; *dinetical*, whirling round; *fulgury*, lightning; *gnathonic*, flattering; *nocument*, harm, &c.

The following obsolete words have been taken at random out of many hundreds to be found in the dictionary, some of Saxon origin, but most of them Latin:

Obtemperate, to obey; *naufrage*, wreck; *obequitate*, to ride about; *postnate*, subsequent; *proditor*, a traitor; *refocillate*, to refresh; *resile*, to recoil; *rixation*, a quarrel; *scelerat*, a criminal; *secundation*, prosperity; *sicker*, sure; *singult*, a sigh; *sollar*, a garret; *sopition*,

sleep; *strepent*, noisy; *subtiliate*, to make thin; *impester*, to vex; *indagate*, to search out; *indign*, unworthy; *jument*, a beast of burden; *loring*, instructive discourse; *malaxate*, to soften; *moliminous*, very important; *meticulous*, timid; *reclude*, to open; *won*, a dwelling; *wis*, to think; *swipper*, nimble; *spane*, to wean; *rede*, to counsel; *seely*, fortunate, *munite*, to fortify; *mugient*, bellowing; *gast*, to frighten; *gemote*, a meeting; *ethel*, noble; *depectible*, tough; *costrel*, a bottle; *azyme*, unleavened bread.

A study of the obsolete words is exceedingly instructive as showing how language dies piecemeal, and is sloughed off like the hardened scales of the skin. We also see the fertility of invention by which new words are constantly being added or introduced, and the resulting struggle for existence. It is curious to observe, too, how words may become obsolete in one sense, perhaps their principal and appropriate sense, and still hold their existence by doing some other duty. Thus, formerly *knave* meant a boy, then a servant, and the beginning of one of the epistles of Paul, which now reads, "I, Paul, a servant of Jesus Christ" is rendered in an old version, "I, Paul, a knave of Jesus Christ." *Prevent*, which formerly signified to "assist" by "going before" now means to effectually hinder. *Meddle* used to mean simply to mix or mingle; now it is restricted to mixing in an intrusive or officious sense. *Miser* formerly signified merely a wretched or afflicted person, now it is applied only to a rich person wretched from stinginess and greed. *Pretend* means literally to *hold out* a thing as if at arm's length, and probably was first used with reference to material things only, but this sense of the word is entirely laid aside. *Captivate* formerly signified to seize a prisoner as in war. This meaning has fallen upon the word *capture*, and now captivate is almost exclusively devoted to moral seizure. The radical meaning of *buxom* is to bow or bend, hence obsequious, obedient, &c., applied to wives and young women. But this meaning is now lost, and the word applies to quite different qualities. *Renege* formerly signified to deny or disown; now the word, somewhat modified, is confined to a false denial of suit in a game of cards. *Wang* used to be a shoe-string, and *whang* a leather thong. Now *whang* alone is used for the leather strings by which the sections of leather belting in machinery are fastened. Then again we may observe that many words have lost their relatives, which to all appearance, had as good right and prospect of life as they. Thus we no longer use *munite*, to fortify, but retain muniment and munition; *prow* (adjective), for valiant, is obsolete, but *prowess* (the noun), for valor, still flourishes; *serr* and *serry*, to crowd, have gone out; but *serried* still does a restricted duty in describing dense ranks of soldiers; *mure*, a wall, has gone, but we still use *immure*, to inclose with walls. We have *mercy*, but no longer *mercify*; we have *minority* but no longer *minorate*; we say "we had as *lief*," but the comparative *lever*, has been cast aside for *rather*, the comparative of *rath*, while *rath* itself is now seldom or never used. *Icon*, an image, is obsolete, but we keep *iconoclast*, an image breaker,

iconoclasm, &c. *Sess*, a tax, is out of use, but we retain *assess*, to impose a tax. We still retain *tinder*, meaning an inflammable substance, while we have discarded the verb *tind* to kindle. We have cast aside *wis*, to think, while retaining *wise*, *wit*, and *wisdom*. *Wry*, to twist, is out of use, while *wry* (the adjective), twisted, we retain. We have discarded *won*, a dwelling, and *wone*, to dwell, but have retained derivations of *wone*, viz., *wont*, and *wonted*, meaning accustomed or used. Since 1611, 388 words or senses of words used in the Bible have become obsolete. This is about one out of every fifteen. Details like the foregoing might be multiplied indefinitely. Their study shows how words spring up under the influence of the various objects in the environment, in accordance with the manner in which they affect us, and the ideas they produce in us; how, as gradual changes are produced in our ideas by new experiences and impressions, their expressions in words change correspondingly, new ideas requiring new words or new applications of old ones. New words are obtained by importations from other languages, or by modifying old words. Very rarely indeed, is a word coined or invented, and when it is, it must necessarily be an imitation of nature or of another word. Since man's dependence upon his environment has always been as it is now, it is reasonable to conclude that the growth and modification of language has always proceeded as it is now doing. The history of 300 years is enough to furnish us the principles involved in that of all the past.

Since language is the expression of ideas, its development has necessarily proceeded in the same order as the development of ideas. The first ideas must be of the simplest and most obvious, uncompared and unclassified facts. After the internal sense organs have been stored with these facts, further development of ideas throws these facts together, forming comparisons, generalizations, and classifications. Following this order, words first expressed single things, next they expressed qualities and motions, and lastly the relationships of things to each other by their qualities.

It has been shown that we cannot have any idea except of sensible things, and that ideas which we have, or suppose we have, of supersensible things, have in reality been derived from sensible objects. Language follows and illustrates this fact. All the words which we use to express ideas of things which are beyond the immediate reach of our senses, are words which originated with reference to tangible and visible things. Thus, the word *spirit* comes from the Latin spirare, to draw breath, and from the same source we get aspire, inspire, transpire, respire, &c. From the root *an*, which in Sanskrit means to blow, comes the Sanskrit *anila*, the Greek *anemos*, the Latin *anima*, wind; the Latin *animus*, mind; English animate, animal, &c. The Sanskrit *dhu* means

to shake. From this root comes the Greek *thyein*, to rush, to move violently; and *thymos*, the *mind*; the Sanskrit *dhuli*, dust; and *dhuma*, *smoke*; Latin *fumus*, smoke; English *dust*, to *fumigate*, to *fume*, &c. From the root *ma*, to measure, are derived the Greek *mimema*, an imitation, i. e., a repeated measuring; *mimos*, a mimic; *mimo*, an ape (because he imitates); the Latin *imago*, image, picture, dream (for *mimago*); *imitor*, to imitate (for *mimitor*); and of course the English words mimic, imitate, image, imagination, &c. So, in order to imagine a thing, all we do is to measure it over and over. To *apprehend* is to grasp at a thing, to *comprehend* is to grasp it together. To *adhere* to one's opinions is to stick to one's opinions. To conceive is from *concipio*, from *con* and *capio*, to take and hold together, to *instil* is to drop or pour in, to *disgust* is to create a bad taste, to *disturb* is to throw into disorder. *Tribulo* is Latin to thresh grain; *tribulum*, the machine for doing it, consisting of a drag, or dray studded with iron teeth. From this comes the English tribulation, applied to a condition of the "mind." Tribulo is related to *tero*, to grind; and *tritus* and *contritus*, ground, bruised, &c., from which we have in English, *contrite*, "broken hearted for sin;" and *contrition*, penitence. From the same root is *attrition*, sometimes applied to an imperfect repentance. It is called slang to say a person is "all torn up" in his mind, but it is expressive in much the same way as *contrite*, "all ground to pieces," or "dragged under the threshing-machine," as in tribulation. The Latin *pendeo* means to hang; hence, *pendo*, to weigh, and *penso*, to weigh in the mind, and the English *pensive*. From *pendo* is *pondus*, a load or weight, a *pound*; also ponderous, and *ponder*, a mental operation. From *pendeo* we also get suspend and suspense. We "suspend judgment," and we are in a state of suspense; that is, hung up in our minds. From the root *lubh* comes the Sanscrit *lobha*, desire; the Latin *libido*, violent desire; and *libet*, it pleases; German *belieben*, to be pleased with a thing; English *believe*. From the same root comes *love*. (Müller.) So that belief is that which pleases and that which we love. This indicates the history of the human conception of belief. We commonly speak of belief as intellectual assent, but to the early framers of language it was rather emotional assent, and this definition would often fit the case yet.

The word *curro*, to run, (from the root kar or har) has furnished numerous words for the expression of our super-sensible ideas. Thus, when we *incur* a risk, or *incur* the displeasure of somebody, we literally *run against* the risk or the displeasure. When our opinion *concurs* with that of another, it literally *runs with* it. When something *occurs* to my mind, it *runs up* to it. When your thoughts *recur* to the past, they *run back* to it, &c. We thus see the impossibility of having ideas independent of sensible things.

From a common root are derived the Latin *ango*, to choke or throttle; *angina*, the quinsy; *angor*, pain, vexation; *anxius*, thoughtful; and the English anxious, anguish, anger; all applicable to mental states, the primary sense being to press or squeeze. The Greek name for spirit, *pneuma*, is that which also means wind, blast, a tempest, &c. Hence it was used to signify breath, then life, then mind, then inspiration; and when it was necessary to have a word to designate the third person of the Christian Trinity, He was called the Holy Pneuma. John 4:24, *Pneuma o Theos.*—"God is a Spirit." Likewise in the old testament the Hebrew *ruach*, wind, is used to signify the Spirit of God. It is thus used in the second verse of Genesis, while in verse 8 of chapter 3, *le ruach haiyom* (evening breeze) is rendered in our version, "cool of the day."

The American Indians had a pretty general belief in a future state, and an immortal part or soul. This soul some thought was in the bone, and their word for soul corresponded with that idea. In the Iroquois language, *esken* is bone and *atisken* soul, that is, that which is within the bone. In an Athapascan dialect, *yani* means bone, and *i-yune* is soul. The Lower Pend d' Oreilles were destitute of any idea of future state, spiritual existence or anything of the kind, and therefore had no word for soul. When the Catholic Missionaries undertook to teach them Christianity it was necessary to clothe the conception of *soul* in such language as they could understand, drawn from material things. The half-breed interpreters solved the difficulty by telling them they had a gut that never would rot! This is a sufficiently materalistic dress in which to put the conception, but after all, the names given to it by more cultivated races, are equally those of material things. In the Aztec and related languages, *ehecatl* means wind, and also shadow and soul. Among the New England tribes, *chemung* meant both shadow and soul, and in the Quiche, of Central America, *natub* meant the same things, and so did the word *tarnak* in the Eskimo tongue. In the Mohawk, *atonrion* means to breathe, and *atonritz* stands for soul.[1]

In the Welsh language is the word *cas* which signifies to separate, to drive off. From this signification it passes in Welsh to mean also to defend, a castle, hatred and envy, also hateful and odious; *casnawr*, a hater, a persecutor; *casnori*, to persecute, to chase. In English, from the same root come *cast*, to throw or to pour, *guess*, *gust*, *gush*, *gas*, *aghast*(?), *ghastly*, *ghost*. There are also many words from the same root in other European languages. Thus a *guess* is something thrown together, and the word preserves the same idea of it that is contained in the word *conjecture*, from the Latin *conjicio*, to throw together. In *gush* and *gust* the idea of pouring forth and passing is expressed, and in *gas* and *ghost* this idea is but little modified. By *apparition* is meant

[1] See Brinton's Myths of the New World, p. 234.

simply an appearance, but as we had other words meaning the same thing, *apparition* came gradually to be applied exclusively to a ghostly appearance. *Specter*, another word for ghost, means simply something seen,—from the Latin *specto*, to behold.

I take it that, in such cases as the foregoing, no one will claim the more involved and mystic applications of a word to be the original. No one supposes that the Mohawk *first* named his soul *atonritz*, and afterwards from some fancied resemblance called his breath *atonrion*. So I hold that generally the root word is the one which expresses the simplest and most obvious idea, and the others, the derivatives. The philologists in tracing Aryan speech to roots, have often given us terms expressive of abstract ideas for roots. Undoubtedly the top story of language has, to a great extent, been erected on abstractions, but the ground floor certainly was not. My contention is, that before any word had a general or abstract application, it had a special one. In some cases the derived words can yet be traced to words which are at the same time roots. Thus *gu*, as shown above is both a root and a word. So are probably *cat* and *dog*, and perhaps *horse* and *su* (sow). In Sanskrit *su* means to generate; *savitri*, the sun; and *savitri*, a mother; *sunu*, a son. Greek *us*, a sow or pig; *uios*, a son. Latin *sus*, a sow; *suinus*, belonging to swine. Anglo-Saxon, *su-gu*, *su*, sow; *swin*, swine; *sunu*, a son. English, *sow*, *swine*, *son*, *sun*. In the foregoing the obvious root word is *su*, the sow. From the prolific qualities of this animal comes the obvious application of her name to the sun, the great mother of all, and to mother and son.

Skeat gives 461 roots for the Aryan tongues, which number is doubtless too small, as a good many words still remain to be accounted for. But of the 461 over 90 are homonyms, the same word or root being used to designate more than one conception. The root *ar*, for example, is used for four conceptions, viz.: (1) *ar*, to plow; Latin, *arare*, Gothic. *arjan*, Anglo-Saxon, *erian*, to plow; English, *arable*, *ear*; *Aryans*, (*people who plow*). (2) *ar*, to go; Sanskrit, *ri*, to go; Greek, *ornis*, a bird; Latin, *orior*, I arise, *alacer*, quick; English, *ornithology*, *proselyte*, *origin*, *order*, *altar*, *earnest*, *run*, &c. (3) *ar*, to drive or to row; Sanskrit, *aritra*, a rudder; English, *oar*, *row*, *rudder*, &c. (4) *ar* or *ra*, to gain, acquire, fit; English, *aristocracy*, *harmony*, *arithmetic*, *arms*, *art*. Very likely these four were originally identical, traces of a common conception prevading them all. This is also true of other homonyms. If it were true of all, Skeats' list of Aryan roots would be reduced to about 300. Probably it would be safe to say that all the Aryan tongues have been constructed on a basis of not over 500 or 600 original expressions. The great expansion of the vocabulary which has taken place in all languages above the savage type, has been accom-

plished by combinations of the roots, which in all cases form their foundation. This combination in its first stage or aspect is called "agglutination." The principal root in the combined word is preserved without mutilation, as are also to a greater or less degree the other words which have been tacked to it as modifying and explanatory adjuncts. As soon as words are built up in this, or in any other way, they become subject to phonetic corruption, which has been carried to the greatest extreme by the active peoples speaking the Aryan languages. People in a hurry will cut short their pronunciation of words. They do it now and always have done it. We see it in the rustic abbreviations of 'backer, 'tater, 'lasses, and those common to all classes, by which words ending in *ing* are snipped of their final *g*. A vast list of words mutilated in that way could be produced; such as Naples for Neapolis, Woorster for Worcester, Coblentz for Confluentes, York for Eboracum, Carthage for Qartachadashat, [1] &c. Words adopted from one language into another are usually mutilated, as shown in the following words as they appear in French after adoption from the Latin, and in English after adoption from the French. Thus, Latin *scutarius*, is in French *escuier*, and in English *squire*; historia becomes histoire, story; Egyptianus, Egyptian, Gypsy; extraneus, estrangier, stranger; capitulum, chapitre, chapter; dominicella, demoiselle, damsel; paralysis, paralysie, palsy; sacristanus, sacristan, sexton. Hydropsis in Latin is dropsy in English. (Müller.) It seems like a great change from one of these Latin words to its derivative in English, from scutarius to squire, for example; but the Latin words themselves represent a change as great or greater. The original root elements of which they are made up have become so clipped, reduced or otherwise distorted, and the fragments so welded together that it is often difficult even for the expert philologist to restore the word. By this welding process pronouns have become incorporated with verbs, the auxiliary verbs with ther principals, prepositions with their nouns. Languages that have got into this condition are called inflectional languages. The word loved, is love-did, or did-love. The Latin, habeo, habes, habet; Gothic, haba, habais, habaith, (I have, thou hast, he has,) contain the root and the pronouns, completely incorporated.

The Latin *scutarius*, from which we get our squire, is a maker or carrier of a shield, and is from *scutum*, a shield. *Scutum* is a cover or protection, and is from the root *sku*, (a) cover. From the same root comes *cutis*, the skin, *scum*, *sky*, and many others.

With the 500 or 600 Aryan roots have been constructed vocabularies reaching, with their phonetic variations in the different Aryan languages, several hundred thousand words. In Chinese there are about 450 roots or separate sounds, which are raised to 1,263, by various accents and in-

[1] This word as well as Neapolis means *Newtown*.

tonations. With these the Chinese vocabulary of about 42,000 words has been produced. Hebrew has about 500 roots, and the old testament is said to contain 5,642 words. F. C. Cook has formed a list of about 250 words, which he claims are substantially identical in Egyptian, Semitic, Aryan and non-Aryan languages. From this he argues the original unity of language and of the human race. A consideration of the foregoing facts shows us how language has become developed to vast proportions from very small beginnings, in a perfectly natural and necessary way. It required no antecedent purpose to start it or to keep it going after it was started. Beginning in gestures and cries which expressed states of feeling, it grew to express ideas as soon as ideas were formed. As soon as we realize that muscular contraction in limb, jaw, or larynx, is a result of a condition produced in the internal sense organs by some cause in the environment, we have laid the foundation of the science of language. The enormous superstructure erected upon this foundation may well arouse admiration and astonishment, but it should not bewilder our understanding for a moment. Language proper begins with the first animal which makes any sort of a signal, visible or audible, for the purpose of arousing the attention of another. It is difficult to determine precisely the stratum of animal development in which this first occurs; but we are bound to admit it as well established at least in all animals which possess the isle of Reil, since it is settled that in the case of man that is the part of the cerebrum superintending articulation. Most of the higher mammals have a greater or less development of this region. (See ch. 58). The apes are better developed here than any other animal except man, and it is well known that they have calls and signals with definite significations. One, for example, will invade a garden or orchard in the capacity of a scout, the rest waiting outside till he is satisfied and gives the signal that the coast is clear, whereupon they all swarm in.

Dr. R. L. Garner, of Roanoke, Va., writing in the New York World, June 8, 1891, gives an interesting account of his researches in the language of monkeys. He assigns the most advanced language to the Capuchins, although every monkey tribe possesses a dialect of its own. He says, "the Simian tongue has about eight or nine sounds, which may be changed by modulation into three or four times that number. They seem to be half way between a whistle and a pure vocal sound, and have a range of four octaves, and, so far as I have tried, they all chord with F sharp on a piano. The sound most used is very much like "u," "oo" in shoot, the next one something like "e" in be." He has not observed them use a, i or o, but has discovered faint traces of consonant sounds in words of low pitch. The languages of the different races are fundamentally different, the more sociable and gregarious

tribes possessing the most copious. But each language breaks up into dialects in different communities, as it obviously must. The words are monosyllabic, ambiguous and collective, having no negative terms except resentment. The words refer to the most common things in their lives, as food, pain, &c. Strange monkeys when shut up together will come to understand each other's language, but will not usually attempt to speak it.

It is not possible that any two communities of monkeys have the same language. Those having the same forms of vocal organs would utter the same sounds, but different families disconnected from others, would establish different applications of them. Thus, one of Mr. Garner's monkeys had a word for milk, which he recognized when uttered by Mr. G., but that was probably only his meaning of the word, and a monkey of another family, while necessarily using the same sound, would attach to it some other meaning. He finds the language of the chimpanzee to be poor, probably because though intelligent it is an unsocial animal.

Birds, too, have genuine language, as shown by their actions. Hen talk has been, in part, translated into English. The vocabulary is not extensive, but it answers the purpose. By one signal the little ones are called to the protection of the mother's wings, by another they are called to dinner, by another they are warned to scatter and hide from the hawk, &c. This is genuine language under its strictest definition. (See also cases in chapter 77.)

CHAPTER LXXXI.

THE EGO, OR PERSONALITY.

It is said that when persons are on the point of drowning, and also, in some cases, when under the overwhelming terror of a great impending danger, an entire picture of their whole history flashes in one instant into their consciousness. They remember everything that ever happened to them, or that they ever did. The reason of this, no doubt, is, that at that moment every memory cell in the brain is stimulated, and gives its characteristic and usual recollection. Under ordinary conditions, by no possible effort could a person direct attention to more than one or two memories at once, although he might have a rapid succession of them. When all the memory organs are stimulated at once, as in the cases named, the subject experiences for the moment, a consciousness of his whole personality, or the whole of that portion of it that ever becomes the subject of consciousness. This being the case, it follows that in ordinary states our consciousness at any one time can

relate to only a part of our personality. To our consciousness, therefore, our personality does not appear precisely the same for any two consecutive periods of time. We see ourselves piece-meal, and as attention wakes up first one memory and then another, we experience the sensations they are qualified to give, some pleasurable, some painful, and some indifferent. We thus appear to ourselves through our feelings, and to others through the expressions of them, different at different times, in accordance with the sort of memories that are active. The sum of our feelings at any one moment constitutes all there is of our *conscious* ego at that moment, but they usually include a sub-consciousness of other memories not active, which contain elements competent to reconstruct the conscious ego and make it feel like another one. As these other memories become active, and their recollections attach themselves to the already active consciousness, the successive states of the ego are linked together, giving a feeling of continuity, and binding all into a single one. These different sensations and recollections considered together constitute the total conscious personality. This is constantly being added to as we accumulate additional ideas, and it likewise suffers constant loss and decay through forgetfulness. A person living to old age has usually forgotten much more than he can remember, and the sensations which it is possible for him to recover, are but a small part of those he has had. He has died piece-meal, and at the last there is not much of him left to die. The feeling of identity which one has, that is, the conviction that he is the same person to whom such and such things happened yesterday, last week and last year, depends upon his ability to connect his present sensations with the memory of those past events. When these memories are totally obliterated, he is no longer able to identify himself as having been concerned with such events, and his conscious personality has suffered death to that extent.

But the obliteration of memory will not take place as long as the brain cells, which were impressed with the original sensations, remain healthy and intact. But as soon as a part of the brain is destroyed or atrophied by disease, the memories which were registered in it are lost, and the subject no longer identifies the facts to which the memories related, as belonging to his personality. A hole has been made in his conscious personality, and the part that is gone can never be recovered. Such destruction of brain tissue will entail loss of the feeling of continuity and identity, by which the memories belonging to it had been attached to the rest of the personality. And such loss by disturbing the balance of tension, and the mutual restraints which the different organs exercise upon each other, leads to abnormal and deranged action among the organs that are related to those destroyed, though not actually sharing in their destruction. The sort of consciousness resulting from such

broken and damaged brain is fragmentary, discontinuous, and necessarily false, as to its conception of facts, in some respects at least. Even when the brain is complete we are liable to get wrong sensations of things, and of their memories, and much more so when it is disrupted. So that our consciousness may be wrong in respect to our identity and continuity, just as it may be in anything else. Thus we see there may be a great difference between our *real* identity, and our consciousness of it. Identity and continuity of existence do not then at all depend upon the continuity of the consciousness, or upon consciousness in any way, but upon continued bodily existence, which continuity may be proved by witnesses when the subject himself is incompetent through forgetfulness, disease, or insanity, to trace his identity by means of his memory. More than that, consciousness or at least a persuasion of identity is not conclusive of such identity, since in many instances of insanity the subject believes himself to be another person, and in his speech, manners, and actions he imitates the party he imagines himself to be. Yet a disinterested person who has known this subject, will testify to his identity as being very different from what he fancies it to be. No amount of change which takes place in us cuts any figure in disturbing our identity. We change from day to day, and in maturity and old age we are no more like our youthful selves than we are like another person. In short, if identity depended upon a continuance of form, thought, feeling, &c., all identity would soon be lost, and we should be somebody else every day. But it depends upon contiguous succession, and requires only that each state, experience, and molecular arrangement, be founded upon one that went before, and it is due to its reaction against some new phase of energy from the environment. Identity, therefore, in reality, relates to the body alone, and consciousness depends upon cerebral conditions.

The *feeling of personality* is a union of sensations from the divers parts, associated together so as to form a consolidated, single sensation, the ego or I. It is a true case of e pluribus unum. This feeling grows up in the same way in which knowledge of external objects does. The infant, at first, sees all things, including his own parts, as objective. In the course of time, as the perceptions of relationships and correspondences come to be developed, this one of the ego appears among the rest. He begins to connect the different parts of his body together into a single thing or person, in consequence of the habitual association of sensations derived from those parts. But even after this he is some time in learning himself as a first person. He still regards himself as a third person. He says, "Tommy wants a drink." Doubtless he is assisted in the formation of his notion of himself by the manner in which he is addressed by others, and regards himself as a third person, partly

because others do. But later on he discovers that the object he calls "Tommy" is not, as a whole, related to his sensations as other objects are, but that somewhere about it is the home of these sensations. The different parts of the body, considered separately, are still regarded as objective, and continue to be through life, but still as belonging to the part that holds the sensations. We speak of *our* head, hand, foot, brain, mind, body, blood, &c. As we speak of our different parts alternately, we seem to regard the part spoken of as an external object, and all the rest as the ego. It is in this spirit that the feeling of self-control arises, as shown in chapter 66. Thus, a man will say, "*I* only succeeded by a great effort in restraining *myself* from attacking that man." Here he puts for the "I" those motives of prudence, or that discretion which is "the better part of valor," and for the "myself," that part which felt the provocation, indignation and resentment. The latter appears temporarily as the objective part of the man. If, on the contrary, his indignation became strong enough to control his action, he would describe it by saying, "I became so angry at that man that I just went for him." The ego fathers the action, whatever it may be, and it thus appears to keep company with the will.

Those things with which we are in habitual contact, and which constantly pertain to us, come to be identified with us and to enter into our personality. We speak of the acts which we are accustomed to perform constantly as our "habits;" that is, our clothes. In this we instinctively recognize the intimacy which exists between ourselves and our clothes. We are, in a measure, renewed when we change from old clothes to new, from the rough, work-day suit, to the "Sunday clothes;" and our feelings and deportment toward others are largely influenced by what they have on. A king in his robes of state, inspires a very different feeling from that towards the same man in a tinker's dress, working at a bench.

Maudsley observes that a foreign body, an artificial tooth for example, with which we are in constant sensory contact, becomes, in feeling, a part of ourselves, while a paralyzed or much numbed part of the body comes to be felt as a foreign body. So that an artificial tooth may be a truer part of the ego than a paralyzed finger. The condition on which this is so, is, no doubt, that the artificial tooth is useful to us, and enters into our active life, while the other does not.

It is obvious that every sensation we get from our environment enters into and modifies our conscious personality. In fact it is sensations and the ideas constructed and compounded from them, which together constitute the conscious personality. This feeling of *I myself*, must be different in different individuals, because the sensations have been different. While both savage and civilized men have the five sen-

ses alike, the sensations they get through them are largely different owing to the difference in the environments. The personality of a man with a white skin, red hair, and blue eyes, differs from that of a man with a red skin, black eyes and hair. The differences which appear upon the surface indicate differences in the intimate nature of the cerebral, nervous, muscular and other tissues of the body. These differences are in turn due to the differences in the exposure of the two, and of the races from which they have descended. But the differences which have made their mark on the outside in too obscure a manner to be readily observed, are yet vastly numerous and important, and depend on the immediate experiences of the individual. If one of two sons of savage parents be sent to a civilized city to be educated, while the other remains with the wild tribe, the personality of the two will rapidly diverge. In that of the wild one will be incorporated the impressions of the uncultivated desert, prairie and mountain, and of the wild game roaming thereon; of the comfortless, smooky teepee and its dirty surroundings, of the dogs and ponies, of the barbarous dress, trappings and ornaments, of the scanty domestic appliances, meager cuisine, primitive, unpolished manners, uncleanly habits; conversation carried on in a language poor in words and construction, on subjects relating only to the chase and the commonest actions of a barbarous people, personal anecdote, individual achievement and mythical legend, the scanty and meager traditions of a small tribe of barbarians. The personality of the educated one will comprise impressions as much more numerous than those of the other, as the circumstances, activities, paraphernalia, literature, and ideas of civilized life exceed those of savage life. Dwellings commodious and elegant, cultivated lands, vast factories and shops, complicated and infinitely varied sorts of machinery and appliances; great public works, buildings, bridges, railroads, streets, telegraphs, tunnels; great stores of the accummulated products of labor, exquisite works of art, libraries filled with the experiences, learning and wisdom of the whole race for a hundred generations; schools, colleges and churches, theaters, museums; all these and thousands of other things, with their myriads of details, are so many object lessons making their impressions on his plastic brain, and thus constructing the curious mechanism whose reactions upon nervous energy are his sensations, which together constitute his conscious personality. Now if we imagine each of these two diversely formed persons to be presented with a book on some scientific or historical subject, such book forms a stimulation which will affect one very differently from the other. The wild one will be unable to read it or get ideas from it at all, except such as its external appearance, binding, &c., give. The disturbance to his personality as already constituted will be very small, practically nothing. The personality of the other

will receive modifications and additions. The ideas contained in the book will be compared and collated with others already composing the mind, and the mind will be changed; that is, the brain will receive new impressions and be re-formed in some respects so as to give a different reaction from former ones. The personality of the educated man has become so different from that of his wild brother that it is competent to be affected and altered by a class of stimuli which cannot disturb the latter. And the further this alteration goes, the larger does the class of stimuli become that are competent to effect further alterations. As we express it, the mind is broadened by culture, by education, by books, by travel, &c., while without them it remains narrow. And these terms *broad* and *narrow* are not figurative; they express in general terms actual quantity. There is really more mind where there are more ideas, and vice versa, and if there are no ideas there is no mind.

The infant begins life with a brain inherited from its ancestors, but without a mind. As impressions are made upon the brain through the sense organs, and sensations are roused, the mind begins; each impression increasing the differentiated area of the brain, and the possible reactions in memory and sensation which constitute the mind. We sometimes hear it said that persons have inherited such and such mental characteristics or traits. This is inexact. Mind can no more be inherited than a wave of the hand, a cough, a laugh, or a snore, and while it is true that a child may have the same gestures, the same voice, the same gait in walking as his parent, we understand that he has them because he has inherited bodily parts so exactly counterparts of those of his parent that their reactions are necessarily identical. If a man makes two windmills just alike, he will expect their movements to be alike. And so if two brains are alike, their movements, that is, their *mind*, will be alike under the same stimulation. That the minds of parent and child are so very often not alike is due as much to the unlikeness of the stimuli to which they are exposed as to the unlikeness of the organs as originally inherited. If any two people were at the beginning exactly alike in all respects, and then were exposed to precisely the same environment, their development would be the same, and the feeling of identity would be alike in each. They would believe alike, see all things in the same light, have the same tastes, preferences and aversions. They would be alike in personal appearance, gesture, feature, and dress. Accordingly, we find the people of any particular section of the earth, to have a resemblance to each other. And the longer such people have inhabited such country, the more close and striking their similarity.

It is easy to distinguish a Negro, an Indian, a European, or a Chinaman in a crowd. It is generally easy to distinguish a German or an

Irishman. But it is less easy to distinguish a Bavarian from a Prussian or an Austrian. In other words, we find less difference between people having the same origin and nearly the same environment, than where these conditions are different. And if we continue to narrow the inquiry, we find children of the same parents to bear a closer resemblance to each other than to others, and if it be a case of twins, we are sometimes unable to distinguish them from each other. Not only do they look alike but they act alike, and their opinions are apt to be alike. We say of them, "they are animated by the same spirit." And this expression indicates that we instinctively regard them as having similar minds, which is really the fact, and that involves a common feeling of identity to a considerable extent. Each one knows how the other is affected by a given stimulation, from the manner in which he is himself affected. We thus reach the conclusion that the ego and the feeling of personality are built up by the forces in the environment, and are matters of development and habit.

Whether I think another person feels just as I do or not, is a matter of inference from what I know of his surroundings and education. I feel that I am myself John Brown (say); my feeling of identity consists of the linking together in my memory of what can be recalled of all the sensations that have ever been there, sensations of all the experiences that this organism has ever been subjected to or influenced by. John Smith never had precisely the same experiences as I have. His aggregate of sensations give a resultant feeling of identity different from mine. This series of sensations is associated with the name of Smith as a habit, so that the entire association of sensations, including that of the name, forms a single ego, similar to many others in many respects, yet unique and on the whole, unlike any other in existence.

Since all sensations, from whatever quarter, enter into the composition of the conscious ego, it follows that when there is a failure of sensation of any sort, there must soon be a reduction of the ego. Diseases of the senses then become diseases of the personality. The minds of persons born blind and deaf, are very different from what they would have been if the senses of sight and hearing had been active. None of the conceptions of color or sound can enter into the composition of the ego, and a great many of those relating to form must be wanting, too. If a person loses these senses after having acquired a stock of the sensations, he will no doubt make the most of the stock on hand, and the ego remains, to a large extent, crystallized and unalterable as to such mentality as is based upon them, except that he will probably lose some of them through failure of memory. But it is remarkable to what extent the sense of touch compensates for the loss of sight and hearing. The wonderful case of Laura Bridgman illustrates this in a striking

manner. Although the other avenues from the outer world to her brain were closed, the stimulations which it became possible, under Dr. Howe's admirable system, to project upon her brain through the sense of touch alone, were enough to form there ideas of a vast variety. It is not, indeed, possible that her ideas were like those of other people upon most subjects. But neither can we suppose that the ideas of people with like senses are precisely alike, even when they are supposed to agree. As Locke long ago observed, we have no means of knowing that the color two people agree in calling yellow, appears anything like the same to each. All we can say is that as it appears to one to-day, it will appear to-morrow, and he will continue to call it by the name taught him at first, and the two persons will agree upon the name without the slightest means of knowing that it appears alike to each. If this is true of a simple sensation, it is still more so of ideas made up from many sensations. And to a still greater degree is it true when the ideas of a person with five senses are compared with those of a person having but one. In fact, it is nearly impossible for two people to get precisely the same idea of a thing even when both are supposed to see it under the same light, and from the same point of view.

The sense of touch shown in Laura Bridgman's case to be of so comprehensive a nature, is one which can least be spared consistently with the integrity of the ideas which go to make up our personality. Luys mentions the effect of anesthesia, or failure of the sense of feeling, in a number of cases. "An anesthetic patient, described by Michea, said that his body had been changed, and that he had been transformed into a machine. 'You see,' he said, 'that I no longer have a body.' Another insisted that he was dead from head to feet." "The elder Foville reports the case of an old anesthetic soldier, who said he had been long dead." His name was Pere Lambert. He claimed he had been killed, and that a machine had been made to resemble him. He spoke of himself as *that*. Another, a lady, said she felt nothing surrounding her, that she was in space, and her body had no weight. "The surgeon Bandologue, at the last period of his life had lost consciousness of the existence of his body." He claimed he had no head, and did not know where his hands were. He could feel his own pulse when his right hand was placed over his left wrist, but did not know it was his unless told. These cases depend on partial or total anesthesia, or insensibility of the skin to touch.

The knowledge a person afflicted with such a disease gets of himself, is through the sense of sight, and he sees his own parts as he would see those of another person. It requires a train of reasoning to convince himself they belong to him, and it is a matter of inference, not of feeling, that they do. This indicates that the sense of personality

is chiefly, if not exclusively, an acquired habit. There may be a small basis of heredity in it which is nothing more than the acquired habit of our predecessors stamped in our tissues, but it is chiefly the habit of associating the sensorium with the skin by means of touch sensations, that has finally come to identify the two as a consolidated unity. But when such association is broken up, this feeling of identity is destroyed, and the patient looks upon his personal parts as foreign. They constitute to him, as they do to any other observer, a machine, or a "that."

There are also cases of derangement of the sense of personality, arising from direct disturbances of the brain. "In the congestive period of general paralysis," the brain receives too great a supply of blood, and too much stimulation. The tissues become abnormally erected. The patient may then have too exalted an opinion of himself and his importance—possibly thinks himself king, prince or pope, and possessed of boundless wealth, &c.

Then, there are the diseases of the other extreme, in which the blood supply to the brain is arrested, and torpor and stupidity result. In a patient affected with melancholia and prolonged stupor, ending with death, Luys found the cerebral substance totally deprived of blood. Loss of consciousness in epilepsy is due to local or general stoppage of circulation of the blood within the brain. When it is general, total unconsciousness ensues; but when local, the stupor is partial, like somnambulism, and the patient may act in a strange manner, and perform extravagant or even criminal acts unconsciously.

All diseases of the internal sense organs constitute a greater or less disturbance of the ego. In fact, they cause its reconstruction on an inferior plan.

Maudsley thus sums up his conclusions from such phenomena as these: "The lesson of them is, that the consciousness of self, the unity of the *ego*, is a consequence, not a cause; the expression of a full and harmonious function of the aggregate of differentiated mind-centers, not a mysterious metaphysical entity lying behind function and inspiring and guiding it; a subjective synthesis or unity based upon the objective synthesis or unity of the organism. As such, it may be obscured, deranged, divided, apparently transformed. For every breach of the unity of the united centers, is a breach of it; subtract any one center from the intimate physiological co-operation, the self is *pro tanto* weakened or mutilated. Obstruct or derange the conducting function of the associating bonds between the centers so that they are dissociated or disunited, the self loses in corresponding degree its sense of continuity and unity. Stimulate one or two centers, or groups of centers, to a morbid hypertrophy, so that they absorb to them of the mental nourishment" (*blood*) "and keep up a predominant and almost ex-

clusive function, the personality appears to be transformed. Strip off a whole layer of the highest centers—that highest super-ordinate organization of them that ministers to abstract reasoning and moral feeling—you reduce man to the condition of one of the higher animals. Take away all the supreme centers, you bring him to the state of a simply sentient creature. Remove the centers of sense, you reduce him to a bare vegetative existence when, like a cabbage, he has an objective but no subjective *ego.*"

CHAPTER LXXXII.

MULTIPLE EGO—SEVERAL PERSONS IN ONE.

It was a common notion amongst the aborigines in various parts of America and in Madagascar, that each man has several souls. Pulsations observed in different parts of the body, seemed to them to indicate so many different seats of life. The inconsistencies and contradictory impulses governing the actions of men, also lend countenance to this notion. The Feejians believed everyone possessed of two spirits.[1] St. Paul says, "For what I would, that do I not; but what I hate, that do I." "Now then it is no more I that do it, but sin that dwelleth in me." "So then with the mind I myself serve the law of God, but with the flesh, the law of sin."[2]

The Irish soldier who ran away at the first fire, excused himself by affirming that while he himself was as brave as a lion, he had under him a cowardly pair of legs that could not be restrained from running away.

There is a sort of insanity which appears in two opposite phases, which alternate with each other. In one of these, the patient is affected by great elevation of spirits. He is confident, elated, egotistical, free and open with his private affairs, unreserved, prodigal, full of inflated schemes, extravagant in his ideas, and unrestrained in his deportment. In the other phase he is equally depressed, gloomy, and apathetic. He is reserved, diffident and silent, lacks energy and confidence, and is oppressed by a feeling of incapacity and inability to plan or carry out anything to a successful issue. In these two states the physical condition of the individual is as different as are his feelings and deportment. In the one he has an animated, buoyant and vigorous appearance, the skin is fresh and smooth and soft, and the eyes bright, the pulse strong, and digestion good. In the other, he looks like a different person; his eye is dull, skin wrinkled, pulse weak, digestion poor, and even his hair may become more or less gray. If the patient

[1] Lubbock, Origin of Civilization, 247. [2] Romans 7, 15.

be a woman, menstruation is liable to cease. In general, the patient, while in one of these states, repeats the actions that he performed when in the same state before, and behaves and feels as he did then. But they seldom have any clear recollection, in one of these states, of the things done and felt while in the other. In this respect, however, there is great difference in different cases. This style of insanity is by Maudsley called alternating insanity.

The phenomenon called double consciousness is in its effects similar to that just described, although I think the causes may be very different in different cases. Insane results might come from too little or too great a stimulation, atrophy or hypertrophy, of the same brain cells which, under normal conditions, furnish sane effects, or they might come from the atrophy or hypertrophy of a part only, leaving the rest normal, the result of which would be an unbalanced action. In such cases there would be an imperfect memory on the part of the patient, while in his normal condition, of things done in his abnormal, and vice versa, because the same brain cells are more or less involved in both conditions. But there is another condition of double consciousness in which the acts are not unbalanced, extravagant or insane in either state, but in which the memory of each is independent of that of the other state, and things done in one are totally foreign to the other, not forgotten for the reason that they never were known to that state, the memory of them belonging to a set of cells for the time being inactive, and, as it were, locked up.

A number of examples are given by Abercrombie, which illustrate the forgoing statements. One is the case of a porter, who, in a state of intoxication, left a parcel at a wrong house, and when sober could not recollect what he had done with it. But the next time he got drunk he recollected where he had left it, and went and recovered it. Wilkie Collins' story of "Moonstone," is founded on the known fact that acts performed unconsciously while under the influence of a drug, may be performed a second time if the conditions are again all the same.

Another case is mentioned by Abercrombie on the authority of Dr. Pritchard, of "a lady who was liable to sudden attacks of delirium, which, after continuing for various periods, went off as suddenly, leaving her at once perfectly rational. The attack was often so sudden that it commenced while she was engaged in interesting conversation, and on such occasions it happened that on her recovery from the state of delirium, she instantly recurred to the conversation she had been engaged in at the time of the attack, though she had never referred to it during the continuance of the affection. To such a degree was this carried that she would even complete an unfinished sentence. During

the subsequent paroxysm, again she would persue the train of ideas which had occupied her mind in the former."

A case is related of a young lady who became somnambulistic during a long illness which was complicated with severe symptons of hysteria. While she was in the somnambulistic state her thoughts ran a great deal upon a deceased brother. While in one of these spells she got possession of a locket containing some of his hair. With a view of diverting her morbid thoughts her attendants attempted to take this away. But she resisted and kept the trinket, which she hid under her pillow, and then fell into a natural sleep, during which the locket was removed. When she awoke she remembered nothing of the contest or of the locket, except that she retained a vague, and to her unaccountable, feeling of antipathy against one of the persons who had tried to get the locket away from her. But a few days afterwards she fell into the somnambulistic state again and immediately began to search for the locket under the pillow, and expressed surprise that it was gone, saying she put it there only a few minutes before. The time that had elapsed since her last fit of somnambulism, she was, in this state, totally unconscious of. In this, and all the subsequent periods of somnambulism, she retained an active antipathy to the person first mentioned who had crossed her regarding the locket, until after a considerable time her thoughts became diverted from her brother and ran in some new channel.

It is not always possible to make such examination of the brain of an insane person as will enable the doctor to connect the disease with lesion of the brain, but this has been done so often as to establish the principle that the character of the individual depends upon the integrity of his brain and changes with it. This has been illustrated by cases already cited in chapter 69. Some more will now be given.

"*The Crowbar Case.*"[1] One of the most remarkable cases on record is that of Phineas P. Gage, of Cavendish, Vermont. He was foreman of a gang of workmen in a stone quarry, and at the time of the accident, on the 13th of September, 1848, was charging with powder a hole drilled in the rock. He was sitting upon a shelf of rock above the hole, the powder and fuse had been adjusted, and he was tamping it down with an iron tamping bar. This bar was round and comparatively smooth, three feet, seven inches long, one and a quarter inches in its largest diameter, and at one end tapering for about a foot to a point one quarter of an inch thick. While looking around, he allowed the iron to strike fire upon the rock, and an explosion followed which sent the bar obliquely upward through his head, and high into the air so as to fall several rods behind him, smeared with blood and brains. The iron entered by its taper end the left cheek, and passed obliquely up-

[1] **From a Lecture by Dr. Burt G. Wilder.**

ward and backward so as to emerge in the median line on the top of the head at the back part of the frontal bone, near the coronal suture. Gage was thrown upon his back and moved his extremities convulsively a few times, *but spoke* in a few minutes. He was carried some rods to the road, and then rode in an oxcart three-quarters of a mile, supported in a sitting posture. He got out of the cart with little assistance, and an hour afterward aided only by Dr. Harlow, walked up a long flight of stairs and got upon his bed. The wound bled profusely; the brain protruded through a hole in the skull two inches wide by three and a half inches long, and shreds of brain hung upon his hair. While searching for fragments, the doctor passed the two fore-fingers into the two openings so as to meet; but this was scarcely felt by the patient. His mind was clear for two days, but he was then more or less delirious for about ten days; then he had a lucid interval followed by a serious relapse when his life was despaired of. But on the 28th day he was very clear in his mind; stated how long he had been in bed, how he was injured, and the circumstances attending it. On the 56th day, less than two months after the injury, Gage was improving in every respect; sat up most of the day; ate and slept well; walked up and down stairs and into the street. On the 64th day he caught cold from exposure, but the relapse lasted only a few days and he improved steadily until three and a half months after the injury, when the opening on the top of the head had closed over. In April, 1849, seven months after the injury, his condition was as follows: "General appearance, good; stands quite erect, with his head slightly inclined toward the right side; walks steadily; his movements are rapid and easily executed; vision of the left eye lost; partial paralysis of left side of face; has no pain in head, but says it has a queer feeling which he is not able to describe. Is undecided whether to work or travel; but his former employers, who regarded him as their most efficient and capable foreman, considered the change in his mind so marked that they could not give him his former place."

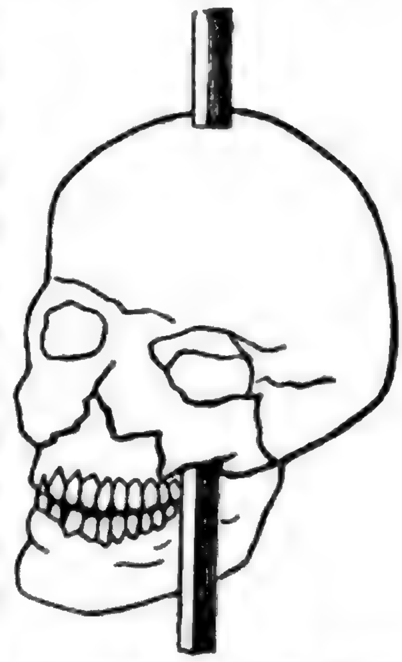

FIG. 399.—Skull of Phineas P. Gage, pierced by a crowbar, Sept. 13, 1848.

"The equilibrium or balance, so to speak, between his intellectual faculties and his animal propensities, seems to have been destroyed. He is fitful, irreverent, indulging at times in the grossest profanity (which was not previously his custom), manifesting but little deference for his fellows, impatient of restraint or advice when it conflicts with his desires, at times pertinaciously obstinate, yet capricious and vacillating, devising many plans of operation which are no sooner arranged than

they are abandoned in turn for others appearing more feasible. A child in his intellectual capacity and manifestations, he has the animal passions of a strong man. Previous to his injury, though untrained in the schools, he possessed a well-balanced mind, and was looked upon by those who knew him as a shrewd, smart business man, very energetic and persistent in executing his plans. In this regard his mind was radically changed, so that his friends said he was no longer Gage. He was accustomed to entertain his little nephews and nieces with the most fabulous recitals of his most wonderful feats and hair-breadth escapes, without any foundation except in fancy.

After trying various occupations he went to South America in 1852, four years after the injury, and during the next eight years was occupied in caring for horses, often driving a coach and six. During the year 1860 his health failed somewhat, apparently from hardship and exposure, and he removed to San Francisco. His health improved somewhat, but in February, 1861, while sitting at dinner he fell in a fit, and soon after had two or three fits in succession. He had no premonition of these attacks, or any subsequent ill feeling; had been plowing the day before the first attack. He got better in a few days, and continued to work in various places; could not do much, changing often, and always finding something that did not suit him, in every place he tried. On May 20th, 1861, he had a series of convulsions, apparently epileptic, lasting until the evening of May 21st, when he died—12 years, 8 months, and 8 days after the date of an injury which had destroyed the anterior and part of the middle lobe of the left cerebral hemisphere. Unfortunately his brain was not examined, but the openings in the skull well indicate the extent to which one-half of the brain was destroyed."[1]

There is nothing to show in the above case, that any part of the memory was impaired; not even the memory of motor speech, although it is highly improbable that the Isle of Reil, on the left side, escaped injury. If it did not, we are bound to conclude that in this case the motor organs of speech were operated from the right side alone after the accident, and that before the accident it at least participated in the speech function. He lost by the accident a part of his moral sense; that is, he thereafter failed to perceive the real relationship between himself and others, shown by his irreverence and want of deference, his profanity, impatience of restraint and advice, disregard for the truth, obstinacy, wilfulness, &c. He also lost his persistence of purpose, and became fitful and impulsive. In short, he became in many respects as a child, or an untutored savage. From this we may learn that the moral and stable elements of character are acquired, and de-

[1] The account of the above case is published in the reports of the Mass. Med. Society, Vol. 2, No. 111, page 330. The skull and the identical bar which was blown through it, are preserved at the Warren Anatomical Museum of Harvard University.

pend upon the differentiation of certain tracts of cortical substance in the anterior and middle lobes of the brain. In the case of Gage, this acquirement appears to have been made chiefly by the left side of the cerebrum, and when these tracts on that side were destroyed, he would become, in a measure, destitute of the faculties represented by them, until the corresponding tracts in the right hemisphere could by education become differentiated to perform the same functions. After his injury he was in the condition of one whose moral education had been neglected till he had reached maturity, and then commenced with a half brain in the unfavorable condition of being stiffened and inflexible from long disuse, and hardened by age.

It is a quite common opinion that the chief seats of the higher intellectual and moral faculties are generally in the anterior portion of the left hemisphere, and that the right hemisphere is decidedly in the background as to morals, refinement and culture. The case of Gage seems to lend countenance to this theory. It does seem reasonable that the centers for civilization and culture should be in the neighborhood of the organs of speech, since the evolution of the former has depended upon and kept parallel with that of the latter. But there are numerous exceptions to the rule that the speech centers are exclusively on the left side.

[1] At the battle of Bazeilles, in the last war between the French and Prussians, F—, a French sergeant 27 years old, was wounded by a ball which fractured the left parietal bone. A few minutes afterward he became paralyzed, first in his right arm, then in his right leg, and then became senseless, and remained so for three weeks. His right side remained paralyzed for a year, and then he recovered so as to show but a slight weakness on the right side. Three or four months after he was wounded, he became subject to periodical, abnormal mental conditions, which lasted from 15 to 30 hours, and occurred after intervals of 15 to 30 days, continuing this alternation of normal and abnormal states for the four years up to the time the account was published. In his normal periods the subject was in good health, intelligent and kindly, and acceptably did duty as a hospital attendant. His abnormal spells began by a feeling of compression about the forehead, after which for some hours he had a dull, heavy feeling, and then without any outward sign he passed into his abnormal state. In this state it appears that he was totally devoid of conscious *sensation* of every sort, hearing, tasting, feeling, smelling and seeing. Dr. Mesnet thought he could see under certain conditions, but the reported facts hardly seem to warrant the conclusion. But the sense of touch, paradoxical as it may appear, was more than ordinarily acute, so that although when punctured with pins,

[1] This account is condensed from that of Dr. Mesnet, published in the Journal des Debats, Aug. 7, 1874, and by Prof. Huxley in his Automatism.

or shocked with electricity, he gave no sign of sensation, he could walk about, eat, drink, dress and undress himself, make up cigarettes, light them with a match, and smoke one after another, and write intelligent letters. He would eat or drink anything given him, even the most nauseous. It is scarcely doubtful that he did all these through touch impressions alone, which acted in part reflexly through the lower ganglia, spinal cord, medulla oblongata, &c., and automatically and yet unconsciously through the cerebrum. The operation of writing letters, for example, required the action of some of the customary internal sense organs.

On one occasion he was walking in the garden under some large trees. His cane, with a bent head, was put into his hand, which appeared to impress his brain that it was a gun, and led to a train of associated memories connected with picket duty. After seeming to listen he called out, "Henri!" then, "here they come, they are at least 20. Let us go at them, we will get the best of them." Then he went through the motion of loading his gun, threw himself on the grass in the position of a sharp-shooter, pointing his gun, and with it following the movements of his enemy.

"The ex-sergeant has a good voice, and had at one time been employed as a singer at a cafe. In one of his abnormal states he was observed to begin humming a tune. He then went to his room, dressed himself carefully, and took up some parts of a periodical novel which lay on his bed, as if he were trying to find something. Dr. Mesnet, suspecting that he was seeking his music, made up one of these into a roll and put it into his hand. He appeared satisfied, took up his cane, and went down stairs to the door. Here Dr. Mesnet turned him round, and he walked quite contentedly in the opposite direction, toward the room of the concierge. The light of the sun shining through a window now happened to fall upon him, and seemed to suggest the footlights of the stage on which he was accustomed to make his appearance. He stopped, opened his roll of imaginary music, put himself in the attitude of a singer, and sang with perfect execution, three songs, one after the other, after which he wiped his face with his handkerchief, and drank without a grimace a tumbler of strong vinegar and water which was put into his hand."

"Sitting at a table, in one of his abnormal states, he took up a pen, felt for paper and ink, and began to write a letter to his general, in which he recommended himself for a medal on account of his good conduct and courage. It occurred to Dr. Mesnet to ascertain experimentally how far vision was concerned in this act of writing. He therefore interposed a screen between the man's eyes and his hands; under these circumstances he went on writing for a short time, but the

words became illegible, and he finally stopped, without manifesting any discontent. On the withdrawal of the screen, he began to write again where he had left off. The substitution of water for ink in the ink-stand had a similar result. He stopped, looked at his pen, wiped it on his coat, dipped it in the water, and began again, with the same effect. On one occasion he began to write upon the topmost of ten superimposed sheets of paper. After he had written a line or two, this sheet was suddenly drawn away. There was a slight expression of surprise, but he continued his letter on the second sheet exactly as if it had been the first. This operation was repeated five times, so that the fifth sheet contained nothing but the writer's signature at the bottom of the page. Nevertheless, when the signature was finished, his eyes turned to the top of the blank sheet, and he went through the form of reading over what he had written, a movement of the lips accompanying each word; moreover, with his pen he put in such corrections as were needed in that part of the blank page which corresponded with the position of the words which required correction in the sheets which had been taken away. If the five sheets had been transparent, therefore, they would, when superposed, have formed a properly written and corrected letter. Immediately after he had written his letter, F. got up, walked down to the garden, made himself a cigarette, lighted and smoked it. He was about to prepare another, but sought in vain for his tobacco pouch, which had been purposely taken away. The pouch was now thrust before his eyes, and put under his nose, but he neither saw nor smelt it, but when it was placed in his hand he at once seized it, made a fresh cigarette, and ignited a match to light the latter. The match was blown out and another lighted match placed close before his eyes, but he made no attempt to take it; and if his cigarette was lighted for him he made no attempt to smoke. All this time the eyes were vacant, and neither winked nor exhibited any contraction of the pupils. From these and other experiments, Dr. Mesnet draws the conclusion that his patient sees some things and not others; that the sense of sight is accessible to all things which are brought into relation with him by the sense of touch, and, on the contrary, insensible to things which lie outside this relation. He sees the match he holds and does not see any other."

In his normal state he is perfectly honest, but in the other he is an inveterate thief, stealing and hiding things with much dexterity, his own things among the rest. In the above performances the automatic, instinctive action of the cerebrum was enlisted, just as in somnambulism and in cases of hypnotism. Any stimulation competent to arouse one of the organs of a series of associated memories, would extend to the whole series, and become expressed in the corresponding motor performances, as in the case of the songs, the picket scene, the writing,

&c. And it appears that in this case the sense of touch alone was sufficient to start such trains of association. It shows the intimate mixture of stimuli from different senses in the same train of associations, that the motor action of F. in writing his letter included looking it over after he had written it, although he certainly did not see it objectively. It is such a case as that pointed out on page 688 (fig. 371), where an organ formed at *d* by the united action of several stimuli setting up motor action at *f* and *g*, is restimulated by a single stimulation, and gives off the same motor action, which, in this case of F., included the motion of the head, lips, &c., just as it had happened in former movements directed by the same brain organ. The same is probably true of the case of writing with the water. The touch impression being different when the water was used, it would stimulate the same train that under the usual conditions would direct an inquiry with the eyes. In the case of the screen, too, no doubt its presence was detected (as in the case of the blind) by the touch sense of the change in the air next the face, and this impression conveyed to the brain centers would work, as in the ordinary habitual circumstances, to raise the unconscious conviction of inability to write under such conditions, and thus defeat the formation of the unconscious will to attempt it. In the case of the singing, too, no doubt it was the new touch impression (heat) of the sun's rays, and not sight that touched off the organs.

This whole abnormal state of F. is explained on the supposition that the injury at the side of the head extended far enough inward to involve the corpora quadrigemina and the optic thalamus, or parts of them, rendering them liable at those periodical seasons, to functional failure, perhaps from want of blood, something in the nature of a partial coma. (See page 743.) The parietal portion of the cerebrum affected at the same time, must have contained organs having an influence upon the conduct, since while they were off duty there was no restraint to the impulse for taking and secreting things.

Writing is performed by hypnotized subjects in much the same way as it was done by F. Mr. Braid's subjects would write with mechanical accuracy with a screen between their eyes and the paper, and he had one subject who would put the final touches on a whole sheet of note paper by going back over it to cross the t's, dot the i's, &c. If the paper with the writing on it were removed, the marks would come in the proper relative positions on the blank sheet below. Sometimes he would feel for the corner of the paper with his left hand, and so be guided in taking a fresh start.

Cases of double personality are now known to be not so very rare. The case of Mary Reynolds, which I give in some detail, will serve as a sample of this sort of phenomena. This account I have abridged from

a manuscript narrative written by her nephew, John V. Reynolds, D. D., pastor of the Presbyterian church at Meadville, Pa., of which narrative I took a copy in 1858. The same manuscript was used in the preparation of an article which appeared in Harper's Magazine for May 1860.

Mary Reynolds was born in England, about the year 1793. Her father Wm. Reynolds, emigrated with his family to this country and settled about the close of the century in Venango County, Pa., which was then an almost unbroken forest. When Mary was about 18 years old she became subject to attacks of convulsions. One of attacks was so severe as to leave her blind and deaf, in which condition she remained five weeks. Her hearing returned suddenly, her sight gradually. One morning, twelve weeks after that severe attack, having gone to bed the previous night apparently in her usual health, though still feeble from the effects of that attack, she slept so soundly that she could not be aroused. When she did awake some hours after her usual time, she had lost all recollection of her former self and life. She had forgotten everything she had ever known. Her father, mother, brothers, sisters, were unrecognized; she had no knowledge of them. She had forgotten how to read and write, she did not know the use of any article about the house, she did not know herself, nor that she had had any previous existence. In a word, she was as if she had then for the first been brought into existence, as to memory of the past not differing from the newly born infant. All that was left her was a diminished stock of words. She had not forgotten how to speak. But until taught the proper application of the comparatively few words of which she had command, her power to speak them was of no particular value. She immediately began as a child to learn her surroundings and made rapid headway. In this, her second state, her intellectual powers were as good as in her first, her memory was excellent though of course it belonged exclusively to her second state, and gave her no account of anything which happened during her first 18 years. She learned very rapidly and in a few weeks picked up a good knowledge of her surroundings and of the ordinary activities of a country life. She became acquainted with her family and friends and most of the persons she had known in her former state. After she had been in her second state about five weeks, she awoke one morning and found herself again in her first state. The change had taken place during sleep and in entire unconsciousness. Her memory began again where it had left off five weeks before. The five weeks were a blank, she knew nothing of what had occurred to her during that time except as informed by her friends. She counted it as so much time lost out of her life. Her friends rejoiced as if they had received her back from the dead, and hoped that this remarkable experience would never be repeated. But after a few

weeks (time not definitely stated) she again awoke in her second state. Then her whole life, with the exception of the former five weeks passed in the second state, was again a blank. Her memory now served only for that five weeks of her second life. She took up the line of thought and of the manner of looking upon life and its affairs, and of progress in the acquisition of knowledge where it was broken off at the close of the five weeks when she awoke in her natural or first state, and pursued it onward as though it had not been interrupted. After this she changed frequently from one to the other during the next 18 years, or until about the year 1829, more than three-fourths of the time being spent in the second state. There was no regularity as to the length of time that either state continued before it was superseded by the other. Sometimes she continued only a few days in her second state, at other times a few weeks or even several months. The transitions always occurred during sleep. In passing from her second to her first state nothing special was noticeable in her sleep, but when passing from her first to her second state her sleep was so profound that she could not be wakened and it often continued eighteen or twenty hours. She usually had some premonition or presentiment of the change sometime before it took place, and the anticipation gave her acute mental pain, especially when she was about to pass from her first to her second state, for she "feared she would never revert so as to know again in this world as she then knew them, those who were dear to her." Her "feelings in this respect were not unlike those of one about to be separated from loved ones by death." Her last change took place about the year 1829, leaving her in her second state in which she continued till the close of her life in Jan. 1854. During this last period of 25 years, she of course had no recollection of the events of her childhood, nor of the interrupted links of her first state between the years 1811 and 1829.

During the early periods of her second state, she exhibited characteristics of a childish nature, sometimes bordering on insanity. She disliked any industrial pursuit, and spent her time in rambling about the fields and woods. She ate and slept but little, sometimes going without either food or sleep for two or three days. She was impatient of restraint, and took strong prejudices against her friends who tried to control her. She was destitute of fear, and ran considerable risk in her rambles, as the woods were infested with wolves, bears, rattlesnakes, and other animals. Once, on horseback riding along a path, she encountered a bear, which she afterward described as a singular black hog which stood erect on its hind legs, grinning and growling at her, and greatly frightening the horse. She refused to allow the horse to turn back, and was about to dismount and drive the bear away with a stick, when it fortunately saw fit to retreat, occasionally turning about and

growling. At another time she encountered a rattlesnake, which retreated under a log heap. She seized its tail, but lost her hold, and then reached into the hole after it, without success. One person, a brother-in-law, was, during this period, able to control her. She felt obliged to obey his orders, literally, but would cunningly evade them when she could. One morning, having commanded her not to ride over the hills that day, she took advantage of the phraseology of the order as soon as he was out of reach, by riding through all the hollows and ravines in the neighborhood. She gradually outgrew these eccentricities, and developed in this her second state into a well-rounded and properly balanced maturity. Of course, in each of her states her surroundings, her acquaintances and friends were nearly the same, and the moral and religious influences to which she was exposed were almost identical in each. Yet it is remarkable that her character and disposition in the two states differed so widely that no person would imagine the two characters could belong to the same person. All her acquirements in her second state were made under very different circumstances from those of the first. Although in her second state she had totally lost the power to read and write, which belonged to her first, yet when an opportunity to learn was given her a year or two after her first change, she learned to read in easy lessons in one day. And she also soon learned to write, but when she first began, she reproduced the copy set before her, proceeding from the right hand toward the left. Her chirography was, and always remained, totally different in the second state from what it was in the first. In her first state she was quite destitute of the imaginative faculty. In her second, her imagination was quite active, and discovered itself in a disposition to write poetry, in writing which, though not of a high order, she was very ready. In her first state, her reasoning powers were moderately good, but perhaps slow; in her second, they were far more active and lively, probably not quite so reliable in their conclusions. In her first state she was steady and patient of application; in the second, more impulsive and impatient. In her first state she was quiet, serious, sedate, and of almost a melancholy disposition, and she looked upon the remarkable condition into which she had fallen as a severe affliction from the hand of Providence, and dreaded a relapse into the opposite state, lest she should never recover from it, and nevermore know as such the friends of her youth nor her parents as she wished to know them, as the guardians of her childhood. In her second state she was cheerful, even immoderately gay in spirits, frolicsome, fond of fun and jokes, ardent in her friendships, extravagantly fond of society. While in this state she always dreaded a return to the other, because she regarded the state she was then in as a happy and joyous phase of life, and understood the other to be a dull and stupid one.

There was one department of her memory belonging to her first state, which, though lost like the rest, appears to have been rather suddenly recovered, and that was her knowledge of the Bible. One Sunday, soon after she had fallen into her second state, she wanted to go with the rest of the family to church at Titusville, for which she saw them getting ready, although she did not then know anything about the church, or what preaching meant. To her great dissatisfaction she was not allowed to go, but the following night she had a very vivid dream, in which was pictured a great, green plain covered with a throng of people dressed in white. There was also a fine river, and there was delightful music of people singing as they passed to and from the river. In the middle was a platform, to which a preacher of majestic bearing ascended, and from which he delivered a sermon. She even remembered the text, Rev. 3–20. She also in this dream thought she saw a sister who was dead; and in subsequent dreams she often seemed to see this sister and another particular friend also dead, neither of whom were known to her at all in the waking hours of her second state. After this remarkable dream, which evidently marked a refunctioning of that particular patch of brain relating to this special memory, she was able to quote the scripture she had been familiar with in her first state, and this long before she had learned to read in her second state.

The following anecdote illustrates her condition: Her brother John, afterwards father of Dr. John V., had settled at Meadville, and was living in the family of Mrs. Kennedy, then a widow, to whom he was afterward married. Miss Nancy Dewey was also an inmate of the same family. Over a year after Mary's first change, and while she was in her second state, she stole away on horseback from her home in Venango Co. and made her way to Meadville, nearly 30 miles, to visit her brother John, to whom she was much attached. Her friends, finding out where she was, allowed her to remain a few weeks. She and Miss Dewey soon got to be great friends, and one day, in a rollicking mood, they contrived some practical joke to be perpetrated on John during the night. During the night, however, Miss Mary had a relapse into her first state, sleeping soundly as usual. Miss Nancy also failed to wake till morning. On awaking, Mary perceived that she was in a strange place. She knew nothing of her surroundings, nor of her room-mate Nancy, nor of the joke they were to have played on John, of which Miss Nancy at once commenced to speak. She dressed herself, and, in a state of silence and uncertainty, waited for something to turn up which would show her where she was. As soon as she saw her brother, she knew she must be in Meadville. He soon perceived the state of affairs and introduced her again to her friends. After her return to Venango, which happened soon after, she roomed with a sister, and one

night aroused her with the exclamation, "Come, Nancy, it is time to get up and play the trick on John." She was now back in her second state, and her mental activities recommenced where they were broken off that night in Meadville.

During the last 25 years of her life, nothing extraordinary happened to her. At one time she taught school, and gave satisfaction. She was a consistent member of a church. During her last years she lived with her nephew, Dr. John V. Reynolds, and superintended his household affairs in an acceptable manner. In accordance with a wish she often expressed in the phrase, "sudden death, sudden glory," her death was sudden. In apparently usual health, she was engaged about some domestic matter, when suddenly she raised her hands to her head, exclaiming, "Oh, what is the matter with my head!" She fell to the floor in a state of insensibility, and was at once carried to a sofa, where in a few moments she breathed her last. Her tombstone in the cemetery at Meadville bears her favorite phrase: Sudden Death, Sudden Glory.

There is much in this case to countenance the theory of the second place occupied by the right hemisphere. Supposing the left hemisphere to have been the organ of the first person, it had received all the education for the first 18 years of the lady's life, and when it came to be inhibited, the right side was brought to the front, and exhibited its inherited instincts to be very different from those of the other side; and while in many respects more desirable, they belonged to a less restrained and mature age of civilizatio...

The alternate shifting from one side to the other, of the spasm, which caused the inhibition of first one hemisphere and then the other, has many parallels in other cases, and can often be accomplished artificially by the use of metals or magnets, and in such cases seems to be due to some disturbance of the magnetic and nervous fields of force surrounding the nervous system. But the details of the action have not been ascertained.

Dr. Brown-Sequard gives an account of a boy whom he met at Notting Hill, London, who had two mental lives. Generally once a day and about the same hour he would suddenly become motionless in the position he happened to be in, whether standing or sitting, his head would droop forward, his eyes close, and for one or two minutes he seemed to be asleep. Then he would start up again and appear bright and alert. But as it was ascertained, during this brief sleep he was accustomed to pass into a second mental condition totally severed from the first. The time he remained in this second state lasted from one to three hours when he again passed through a brief period of sleep, and emerged again in his first state. His memories in the two states were

totally distinct from each other, but each was complete and continuous, considered by itself. If all the periods between his abnormal naps had been numbered continuously, his first state would be represented by the odd numbers and the second state by the even ones; like the two sides of a street which has all the odd numbers on the left and the even ones on the right. Once Dr. Brown-Sequard was present when he experienced one of his transfers to his second state. His first person was well acquainted with the doctor, but when his second person woke up, he asked his mother to introduce him to the strange gentleman. After this introduction both persons knew the doctor, but neither ever remembered any incident that happened to the other. Dr. Brown-Sequard says he has seen three other cases of that kind and infers they "cannot be extremely rare."

Another case of double personality is reported from Paris, a lawyer named Emile X. He probably inherited a defective nervous organization, his father being eccentric and dissipated, and his mother a nervous invalid. He received a good education and was admitted to the bar. "He is affected with serious hysteria, which manifests itself in him by unconsciousness, disturbance of sensibility, and temporary paralysis of limbs. If he only looks fixedly at anything, or hears a sudden violent noise, or experiences any strong and sudden emotion, he falls into a hypnotic sleep. One day, at a cafe, looking at a mirror he fell into this condition." Another time when pleading in a law court, and looking fixedly at the judge, he fell into a trance and had to be roused before he could proceed. When he gets into these second states he remembers other events that happened at other times in these states, but sometimes nothing of his experiences in the first state and vice versa. His second state appears to be a more lawless and irresponsible condition than the first, and in it he performs eccentric and wayward actions and gets into scrapes. He travels off to distant places, pays visits, gambles, &c. Once he visited an uncle living near Villars, and there he broke "many things, tore up books, and manuscripts, contracted a debt of 500 francs, and was charged with swindling," and condemned by default. Once on one of his trips, he left his overcoat and a purse containing 226 francs, and on returning home and being then in his first state, he could not remember what he had done with them, but upon being mesmerized or hypnotized he was able to tell where he had left them. The periods he passed in the second condition vary in duration from a few minutes to several days, sometimes twenty. His second state appears to be a hypnotic state, and it is probable that it varies in profoundness, sometimes cutting off more of his normal memories than at others, so that while in his normal state he remembers nothing done in the abnormal, yet probably in the latter he retains some memories

of the former. A violent excitement or altercation is liable to bring on the change.

The following I condense from an account of the remarkable French patient, known to the doctors as Louis V. which was written by Fred W. H. Meyers, and published in Proceedings of "Society for Psychical Research," also in 19th Century, 1886:

"Louis V. began life in 1863 as the neglected child of a turbulent mother. He was sent to a reformatory at ten years old, and there showed himself, as he has always done when his organization has given him a chance, quiet, well behaved and obedient. Then, at 14 years old he had a great fright from a viper, a fright which threw him off his balance and started the series of psychical oscillations, on which he has been tossed ever since." His first symptoms were epilepsy and hysterical paralysis of the legs, and at the asylum at Bonneval, whither he was sent, he worked at tailoring steadily for a couple of months. Then he suddenly had a hystero-epileptic attack, with 50 hours of convulsions and ecstacy, and when he awoke from it he was no longer paralyzed, no longer acquainted with tailoring, and no longer virtuous. He had forgotten everything which had happened since his viper fright. His character had become violent, greedy, and quarrelsome, and his tastes were radically changed. Before this attack he had been a total abstainer; he now not only drank his own wine, but stole the wine of the other patients. He escaped from Bonneval, and for a few years had a rough time, occasionally relapsing and getting into a hospital or asylum, and was at one time at Bicetre in charge of Dr. Jules Voisin. He became (it seems) a private of marines, committed a theft and was convicted, but being regarded as insane, was sent to the Rochefort asylum. His condition there is thus described: "There is paralysis and insensibility of the right side, and (as is often the case in right hemiplegia) the speech is indistinct and difficult. Nevertheless he is constantly haranguing anyone who will listen to him, abusing his physicians, or preaching with a monkey-like impudence, rather than with reasoned clearness, radicalism in politics, and atheism in religion. He makes bad jokes, and if anyone pleases him he endeavors to caress him. He remembers recent events during his residence at the Rochefort asylum, but only two scraps of his life before that date; namely, his vicious period at Bonneval, and a part of his stay at Bicetre." This strangely fragmentary memory is the remarkable circumstance in his case. "The physicians of Rochefort were familiar with the efficacy of the contact of metals in provoking transfer of hysterical hemiplegia from one side to the other. They tried various metals in turn on Louis V. Lead, silver and zinc had no effect; copper produced a slight return of sensibility in the paralyzed arm. But steel applied to the right

arm transferred the whole insensibility to the left side of the body."

"Inexplicable as such a phenomenon certainly is, it is sufficiently common (as French physicians hold) in hysterical cases to excite little surprise. What puzzled the doctors was the change of character which accompanied the change of sensibility. When Louis V. issued from the crisis of transfer with its minute of anxious expression and panting breath, he was what might fairly be called a new man. The restless insolence, the savage impulsiveness, have wholly disappeared. The patient is now gentle, respectful and modest. He can speak clearly now, but he only speaks when he is spoken to. If he is asked his views on religion and politics, he prefers to leave such matters to wiser heads than his own." But it is found upon questioning that he has passed into a different state. He now knows nothing of Rochefort, and does not remember that he was ever a soldier. His memory of things is confined to two short periods of his life, not the same ones he remembers when his other side is paralyzed. He thinks he is at Bicetre, and expects to see Dr. Voisin to-day, Jan. 2, 1884, as he did yesterday. And it seems that by various means this man can be transported into at least six separated and partial lives, in which his memory embraces some portion of his past life, and his character, for the time, corresponds with that which predominated then.

In his fifth state, which is brought on by placing him in an electric bath, or by placing a magnet on his head, he appears completely cured. He has no paralysis or defect of sensibility, "his movements are light and active, his expression gentle and timid. But ask him where he is and you find that he has gone back to a boy of 14, that he is at St. Urbain, his first reformatory; his memory embraces his years of childhood, and stops short on the very day when he had the fright with the viper. If he is pressed to recollect the incident of the viper, a violent epileptiform crisis puts a sudden end to this phase of his personality."

The doctor's theory of this case is, that "A sudden shock falling on an unstable organization, has effected in this boy an unusually profound severance between the functions of the right and left hemispheres of the brain. It is not unusual to see the right side of the body paralyzed and insensible in consequence of injury to the left hemisphere, and *vice versa*; and hysterical cases are not unusual in which there is no actual traceable injuring to either hemisphere in which the defects in sensation and motility rapidly shift, as one may say 'at a touch,' from one side of the body to the other." In the case of Louis V. there can be little doubt that the changes that took place in his character and memories were due to the alternate shifting of a spasm of inhibition from one hemisphere to the other, the savage and unruly character appearing when the right side was in activity, and the gentle and civil de-

portment manifesting itself when the left side was in operation. This corresponds with what appeared in Gage's case, and also with the circumstance in the case of Sergeant F., that he had a disposition to steal when not balanced by the sound action of the left side.

But it appears in the case of Louis V. that there is a further subdivision of the hemispheres, and that he has *six* personalities instead of two. This would happen if different patches of brain cells were periodically, alternately, deprived of blood by nervous derangement. We have already met with cases of such partial inhibition in cases of aphasia and loss of special memories, both temporary and permanent. (See pages 679, 680.)

Felida X. is the name by which a French patient is known, who, like Mary R., had a first and a second state, the latter much superior to, and more desirable than the former, for while in it she is free from the nervous pains and inferior, morbid, moral state which troubled her childhood. In her second state she is cheerful and active in her attention to duty, to her children and her shop, and if this is her abnormal state it is a great improvement on the *normal* one.

In the lunatic asylums "we find duplicated individuality in its grotesquer forms. We have the man who has always lost himself, and insists on looking for himself under the bed. We have the man who maintains that there are two of him, and sends his plate a second time, remarking, 'I have had plenty, but the other fellow has not.' We have the man who maintains that he is himself and his brother, too, and when asked how he can be both at once, he replies, 'Oh, by a different mother.'"

The right side of the *brain* (and left side of body) is more subject to paralysis than the left. Among 121 cases of paralysis cited by Brown-Sequard, 97 arose from disease of the right side of brain, and 24 from left. The left side of brain is the biggest, and gets the most blood. There is no left-handed race on earth. Parrots, even, generally perch on the right leg. "Cases have occurred in which the left side of a child's brain has become diseased before the child has learned to talk. In such cases, the child has learned to talk as well as if the left side of the brain had been sound." (The parents of such children have been right-handed.) Not only so, but the movement of the limbs was learned and practiced just as well, showing that one side was competent to assume the whole duty. These children were, however, left-handed.

It is rare that the leg is as much affected by paralysis as the arm, which seems to indicate that the leg is partly connected with both sides. Adults who have lost the power of speech from disease of the left brain, may still recover it by practice, evidently by educating the right side, just as in case of paralysis of right arm, the left has been educated to become *dextrous*.

There are many cases on record in which one side of the brain has become so diseased as almost to destroy it, without producing any very noticeable deficiency in mental action. It follows, in such a case, that all the mental functions are assumed and carried on by the sound hemisphere. If one eye or ear is injured, we can still see or hear with the remaining organ; and there can be no doubt that one hemisphere alone, if properly educated, is able to carry on all the functions of mentality; and there is reason to believe that in most individuals one hemisphere actually does the greater part of the work. Again, a *sudden* injury to one hemisphere, even when apparently slight, may produce very serious results, while a chronic disease, which produces a much greater displacement, may extend so gradually that the uninjured parts may have time to take up the functions abandoned by the diseased portions, so that little or no functional disorder is exhibited.

Some years ago, Dr. Brown-Sequard, advancing the idea that most of our work is done with a half brain, proposed a system of education which should bring both halves into active use, and claimed if this were done, our mental powers would be nearly doubled. This theory might be tested to some extent by observing whether ambidextrous people are smarter than others.

In chapter 73, examples under the head of abstraction, &c., were given, showing a considerable part of the cerebral activity concentrated upon a single line of thought engrossing the attention, while all the cerebrum not thus engaged lay in a dormant condition, so that it could not be fully aroused by an ordinary sensory stimulation. The absurd replies given in such cases, showed nothing but unconscious reflex cerebral action; as a sleeping boy will mechanically and unconsciously say "yes" when ordered to wake up, and yet sleep on. It was pointed out that these states of abstraction are simply more pronounced conditions of ordinary attention, and that our ordinary daily experience involves the division of the cerebrum into two parts, an active and a passive one. The active one absorbs the attention, conscious or unconscious,[1] while the other is in an unconscious and quiescent state. The active portion is generally much the smaller, consisting of only a few organs at a time, and not exactly the same for any long time in succession, except in cases where a person is occupied upon a narrow line of work of long continuance. There is a more or less complete severance between the active and the inactive part, and the latter being deprived of attention, and the power to act, is said to be "inhibited." In ordinary states, the line between the active and the inhibited organs is shallow and wavering, but in the more intense states it becomes more defi-

[1] As explained elsewhere, the essential part of attention is its power of directing the flow of the blood to wasting parts. When the parts are wasted in unconsciousness, this directive agency remains in action unconsciously, which accounts for its apparently paradoxical designation.

nite and fixed, and the banishment of the inhibited organs more com-complete.

When we consider the conditions in hypnotism, it is seen that the inhibition is more positive than in any waking state. But there are different degrees in hypnotism. Some authorities reckon six (see page 808). Edmund Gurney[1] makes but two, an "alert" stage and a "deep" stage, the boundary line between the two being near that between the third and fourth, on page 808. In the alert stage most of the memories belonging to the waking state can be called up, and after the subject has come back to the waking state he can remember most of the things done in the "alert," stage. In the deep stage, too, he can remember a few of the most general circumstances of his waking life, but when awake he can never recall anything done in the deep stage. To this there may be a very rare exception now and then. Again, a circumstance taking place in either state which cannot be recalled when the subject wakes up, may be remembered by him if he be again thrown into the stage in which the thing happened. But a further remarkable fact is that none of the memories of the alert stage can be recalled when the subject is in the deep stage, or vice versa. Mr. Gurney, however, found a brief moment while the subject was passing from the alert to the deep stage, a mere knife edge as he designated it, in which memories of both could be recalled, but on the opposite sides of this narrow boundary are two separate personalities entirely independent and distinct from each other, except in respect to the memories belonging to the waking state, which might be common to both. Moreover there are subdivisions in these stages of hypnotism, and different degrees of inhibition in relation to different organs. A subject may, by the assertion of the operator, be made to believe he is some other person. But this belief requires that the memories of his waking state be inhibited or put to sleep, otherwise they will contradict and expose the delusion. If this inhibition be partial and incomplete, the delusion will be associated with doubt. A subject of Mr. Gurney was told a white handkerchief flourished in his face was a ghost, and in terror he ran away, yet after awaking he remembered that though he was frightened, as at a ghost, he was dimly sensible of its being only a handkerchief. In this alert stage the uninhibited organs mingle their influence with the new organs erected by the suggestion or command of the operator, and co-operate with, or counteract them, as the case may be. A republican subject, ordered to go into the street and raise a shout for Cleveland, would demur and resist, and yet go and obey. I have known such a case. A subject in such case often feels as if there were *two* of him, and there are. One is the body of his organs acquired in a normal

[1] In Proceedings of Psychical Research Society.

way, and built up by the gradual process of assorting and assimilating the stimuli as they come in, and naturalizing them to become a part of the self. The other is the new immigrant idea suddenly introduced by the operator, which is *not* assimilated nor made a part of the self, and cannot be except upon the disintegration or inhibition of some already there. In the waking state a new idea thus introduced takes time to become a part of the self by the re-arrangement or subversion of those already there that are inconsistent with it, or if it is not strong enough to do that, it is itself cast out as a delusion. But in the alert hypnotic state this process of assimilation is or may be suspended as to a delusory idea, and yet the idea may have differentiated its organ and may remain as an irreconcilable foreign person. In the deeper state, when the delusion is strong enough to monopolize the whole attention, all the normal organs of the waking self that are contradictory to it are inhibited, deprived of their blood supply, and put to sleep. The strange delusory organ, which is no part of the ordinary self, is alone left to run the whole machine. And since there is no co-ordination between this organ and the rest, when they wake up again the memory of this strange organ cannot be recalled. The different degrees in hypnotism, then, relate to details of the inhibition of blood from the normal cells. This is no doubt accomplished through the action of the nerves upon the blood-vessels, the nervous action originating from the original impact upon the external sense organs, and being thence propagated inward to the brain. It appears to act in two complementary modes, one in the expansion of certain blood-vessels, admitting the liberation of material for the construction of the new organ or organs; the other, in the contraction of other blood-vessels, causing the cutting off of the supply to organs already there, and reducing their activity.

The impressions made upon the subject when in the deep state, although not connected with the memories of his waking hours, nevertheless possess their own independent control over his movements whenever their activities relate to muscular motion. Commands given the subject when asleep, to be performed when he wakes up, are certainly remembered by the new organs concerned; that is, those differentiated by the stimulus of the command; and they go on and relieve the nervous tension in which they are left, by setting off the muscles in the performance of the action commanded, often to the surprise of the *other* fellow, the normal one, who cannot account for his action, and never imagines it is not his. See case mentioned on page 809. Such cases show the deceitfulness of our subjective notion of having a free will. The new person created in the brain of the subject in deep hypnotism by stimulations from an operator, is just exactly as real a person as the original normal one, or first person, who was created by miscel-

laneous stimulations from all the environment. But the new person is much smaller. He has only a few ideas; only those the operator has given him. The operator is his whole environment, and as the creature cannot rise above his creator, whatever the operator says to him, *goes.* The operator's command is the law of his being, and comprises his sense of duty and his moral code. After all the commands of an operator that are required to be obeyed after the first person wakes up, have been obeyed, nothing more is heard of the second person; his activity is ended, and unless the hypnotic condition is again brought on and more suggestions and ideas added to him, he will remain asleep till death ends both him and number one. The second person, like the first, but better than the first, possesses the obscure power of measuring time. Somehow he counts the days when so ordered, and consequently so constructed, for in such case the order is the stimulation that constructs.

Professor Beaunis, on July 14th, 1884, hypnotized Mlle. A. E., at Nancy, and said to her, "On January 1st, 1885, at 10 a. m., you will see me, I shall wish you a happy New Year, and then disappear." Accordingly on New Years day, 171 days after the order was given, at 10 a. m., the lady heard a knock at her door. She said, "Come in," and to her surprise she saw Prof. B. enter, and heard him wish her a happy New Year; then saw him immediately go out again. She was surprised, also, to see he had on a summer suit; it was the same he wore when he gave the order. She looked out of the window to see him go but saw no more of him. This hallucination when thus worked out became incorporated as part of her first person; it was in fact, objective to it the same as any other act worked out in the waking state. It was a hallucination of the senses in the waking state. But the antecedent reckoning of the time was performed entirely by the second person, as in her waking state she knew nothing of the order given in the hypnotic state. The professor was in Paris, and she in Nancy, on the day she thought she saw him, but she could not be convinced it was a delusion.

The second person built up by the operator chiefly or wholly through the sense of hearing is, as observed above, necessarily a narrow person, composed of only a few organs; but if the first person could be inhibited completely, without involving the sensory organs and their avenues to the brain, it is apparent how new sensory stimulations could go on, if time enough were allowed, and build up a second person every way equal to the first, and perhaps even superior to it. That this has actually occurred in nature is proved by the cases of Mary Reynolds, Felida X., and others mentioned in this chapter. The part of the brain comprising the first person in those cases became totally, or almost totally, sunk in profound oblivion, while the environing stimuli continuing to

work on the vacant territory of brain not before occupied, built up a second person, separate and distinct from the first. It is obvious that, if in these cases the first person had not been inhibited, the stimulations which went into the construction of the second, would have gone to the first, and have been assimilated with it, and the whole have formed but one person. So we have here an absolute confirmation of the conclusion arrived at before, that the (conscious) personality is nothing more than the aggregation of the sensations of the environal stimuli. Wherever we can get together an association of two or more sensations, we get a sensation of personality, and if we can, in any individual, get anywhere from two to six (or more) different aggregations of brain organs, each aggregation disconnected from the rest, we find a separate consciousness of personality going with each one, and the individual is the tenement of two or six or seven persons, as the case may be. It is well if, as in the case of Felida X. and Mary R., only one of these personalities is awake and active at one time. If, as it no doubt happens in some cases of insanity, two or more of these persons are active at once and endeavoring to operate the same nervous and muscular apparatus, the result might well resemble the antagonisms of seven devils or a legion of them. To make such an individual sane you have only to "inhibit" all of his persons except one.

Since every idea that enters the brain is at first a foreign element, its sensation is in reality that of a new personality, and remains so till it is co-ordinated and assimilated with the first one, mutually modifying and being modified by it. The foreign immigrant to a new country, finds himself in the sudden presence of an avalanche of new ideas, which can be only partially absorbed in his lifetime. I once heard a Scotch gentleman, naturalized in this country, relate with much amusement, how his little son, born an American, came home from school one day, where he had been studying the history of the revolutionary war, and told his father with great glee and exultation how "*we* whipped the British." Fancy the "naturalization" of the father, a "Britisher," ever leading him to feel himself one of the "we" as the boy did. A different environment makes a different person. When two are inhibited from each other, they may exist side by side in the same brain. When there is no inhibition, they are superposed one on the other, amalgamated and consolidated into one, as far as their elements are assimilable.

It has been observed that the inhibition in hypnotism is due to the withdrawal of the blood supply from the inhibited parts. When a subject begins to fall into the hypnotic state, his whole brain is in process of being inhibited; that is, the blood flow is reduced to all of it, except the one avenue that connects him with the operator. This, I take it, is like a person going into a profound, natural sleep with a single

idea "on his mind," such as that he must wake at five o'clock, or when called by a particular signal. Mr. Gurney thought the operator possesses a special hold upon the subject consequent upon his particular nervous organization fitting into that of the subject and creating a peculiar *rapport* between them. No doubt this comes to be the case after the habit of controlling the subject has gone on for a considerable time, and mutual adaptations have been established, as in the case of Dr. Dusart and his subject, mentioned in chapter 79; but this hypothesis does not appear to be necessary to account for the essential facts. After the inhibition is complete in the alert stage, except as to the avenue reaching to the operator, the suggestions of the operator admitted thereat proceed to remove the inhibition of those organs, which in the normal state they would naturally associate with or antagonize, without disturbing the rest. This results in the contradictory and phantastic performances of a double personality, in which the two are turned loose at the same time, the small fraction of the normal organs that are awake, constituting one person, and the suggestions of the operator, the other. In the deep stage, few or none of the organs of the normal state are aroused, and the second person, the creature of the operator, alone remains in activity.

A remarkable possibility in hypnotism is the inhibition of sensibility. For example, a lady with a painful abscess on her thigh as big as a hen's egg, which she cannot allow to be touched, is hypnotized, and told that when she wakes up the doctor will empty the abscess, and that it will not hurt her the least bit. She is then brought back to the normal condition, and the doctor proceeds leisurely to squeeze out the abscess, the lady looking on smilingly, without a particle of pain. Delusions usually contain elements of inhibited sensibility, in some form or other. The subject does not see, hear, or feel what he is told he cannot. This undoubtedly implies that sensibility is a sequel of nervous action, which is inhibited like other nervous action when its blood supply is cut off. This is nothing new, however, for we have all along had plenty of evidence that consciousness depends on the nutrition contained in the blood. We have also had plenty of evidence of an activity of the brain organs, which includes all their functions *except* sensibility or consciousness. In normal states the failure of sensibility is due to the failure of blood at a particular place, from various causes, often by its simple withdrawal to other parts, as when one part monopolizes it at the expense of the rest, as in reverie and abstraction; also when the blood becomes impoverished by hunger, &c. (see page 737); or in special parts when benumbed with extreme cold, when the circulation is greatly reduced. In hypnotism, while the immediate cause of the loss of sensibility is still the same, that is, deficiency of blood, the cause of

the inhibition is probably different. Whereas, in the normal state we withdraw attention from organ A by attending to organ B, as may happen to a soldier wounded in the excitement of a desperate charge; in the hypnotic state a new organ C is erected in antagonism to A, and the plus activity of A is nullified by the minus activity of C. This new organ C is a new *person* which is erected when all the normal ones are asleep, and from which all the rest are permanently inhibited, except A, whose sensibility it is destined to strangle. So when the lady with the abscess wakes up, she leaves *that part* of organ A whose action constitutes consciousness of its function, in the lethargic embrace of C. The influence of a new person thus created, does not often last long after its function is performed and its tension relieved.

Some of the effects of the application of magnets in hypnotic experiments made by Binet and Féré, have been related by them in their work on Animal Magnetism. When a subject is made by suggestion to see an imaginary object with the *right* eye, for example, if a magnet be held near the left side of the body, the hallucination will be transferred to *that* side, and the left eye will appear to see it instead of the right. In case the imaginary object is seen by both eyes, if the magnet be brought near, the hallucination will be abolished altogether. The same is true in the case of hallucination of hearing. If, by a suggestion of the operator, a real object becomes invisible to the subject, bringing the magnet near will neutralize the suggestion, and the subject will again see the object. If the subject by suggestion is made to perform a movement with one hand, the influence of the magnet will cause the movement to be taken up by the other hand, and discontinued by the first. Thus, the right hand can be restrained from writing, and the left made to continue it. These experiments appear not to have been repeated in very many cases, but if a magnet has this power of changing polarities, reversing them apparently, it affords a suggestion of similar reversals arrived at in some other way, as being at the bottom of the transfer of inhibitions from one locality to its complement, in case of double personality.

CHAPTER LXXXIII.

CONSCIOUSNESS.

Consciousness, as we think of it in the general lump, is made up of single sensations. Whenever we are conscious, we are conscious with regard to some definite thing or things. Consciousness is not an abstract quality. We may experience several sensations at once, one of which is more distinct and intense than the rest, but the aggregate of

them, constitutes our consciousness for that moment, and when a new direction of the attention brings forward new sensations, the consciousness becomes different. So it is not the same for any two minutes. A great many different names have been given to various sorts of mental action, such as perception, ideation, judgment, volition, &c., and the general term, thought, which covers all these and many more. It was pointed out on page 760 that these mental processes can all be carried on without arousing any consciousness that connects them with the waking state, and that therefore, we should recognize these processes as distinct from sensations. Thus we have sensory impressions which are not sensations but which may give rise to sensations, and likewise we have perceptions, volitions, and thoughts in general, which are not themselves sensations, but which may give rise to them. When a sensation is experienced, whether it be of sight or sound, or of a purpose or a thought, we are conscious of such sound or purpose or thought. It matters not whether the sensation is got as the result of an impact of energy from the external senses, or of one from the internal senses; the physiology of it is just the same. The distinction between conscious brain action and unconscious brain action has usually been ignored, so that the terms used, being applied indiscriminately to one class or the other, produce confusion. Sensibility, feeling, sensation, pleasure and pain, knowledge, &c., which are all sensations and depend upon a common form of energy, and are all covered by the general term *consciousness*, have not been sufficiently distinguished from impression, perception, ideation, reason, and will, all covered by the term *thought*. Consciousness and thought, used as thus defined, principally though perhaps not exclusively constitute the *mind*. Consciousness and thought, then, are different and distinct functions of the nervous tissues, although the former, when it is in activity, is a sequel to the latter and is therefore associated with it, so it is easy to recognize the thoughts that occur during the activity of consciousness, while it is equally easy for those not so associated to escape observation.

It was pointed out in last chapter how sensibility may be inhibited in a particular case without inhibiting the physiological process which precedes and normally gives rise to it. This shows the fact that the functions are really two, and that though so intimately connected as antecedent and consequent, the latter may be suppressed without the nullification of the former. It is true that this appears to be the case in the unconscious cerebration discussed in chapter 75, but it is supposed by some writers that at the time the brain action takes place there is a consciousness of it which lapses before it can be connected with the general consciousness of ordinary life, so it is forgotten. While it may not be easy to prove this view incorrect in particular cases, the facts in hyp-

notism mentioned above do prove conclusively that it is not necessarily always correct. It is without doubt correct in regard to those separate personalities existing in a single individual naturally, as in the cases of Mary R. and Felida X., &c., and in hypnotic subjects in the deep stage. But with these examples of inhibited sensibility before us we are supported in the conclusion previously arrived at, that the greater part of mental action, our thought, is not in any way associated with consciousness, and goes on habitually without ever giving rise to it. On the other hand consciousness arises from the simplest forms of mental action, that is, sensory impression, when the more complicated mental functions, such as reason, volition, &c., are not necessarily brought into activity.

What is it? When we consider the relationship in which consciousness stands, with reference to the forms of physical energy that we are acquainted with, we are compelled to see that it is itself a form of physical energy, or in other words a mode of motion. The first proof of this is its origin. It arises as the continuation of such material impulses as those which produce light and sound, smell, taste, and touch; all these being names for consciousness or sensation arising from the impact of moving matter outside of us striking upon our sense organs. When we say we *see a light*, we express the the fact that a motion of ether outside of us by beating against the eye communicates motion to ether inside of us, and that motion *is* the sensation of *light*. When a bell rings it produces vibrations outside of us, and these produce inside of us another sort of motion in the ether of the auditory centers, which motion *is* sound; and so of the other sensations. Different sensations arise from different sorts of motion possible to the ether and the different rates of vibration possible in these several modes. Thus red is not the name of something outside of us, it is the name of a sensation. When ether, vibrating at a particular rate, strikes the eye, the ether of the optic centers of the brain is made to move in a particular way, *constituting* (*not* "giving rise to") the sensation *red*. A "form of energy" is simply a motion of some particular sort of body in some particular manner, and a change in its form takes place when a transfer of the motion is made from one body to another. Red is a form of energy peculiar to a certain body, namely, a patch of brain cells in the occipital lobe, and when these cells are destroyed there is no longer the motion called red. Sensation then, is no exception to the law that the motion of a body changes or ceases when the form of the body is changed. A flute is an instrument in which a portion of air is partitioned off from the body of the atmosphere, and thrown into vibrations which are fast or slow, as the tube of air is made short or long by fingering. It gives no vibrations unless energy is ex-

pended upon it in the shape of a current of air. The function of the brain cell is silent also, unless the energy of a body outside of itself is expended upon it. Each single cell is probably adapted to produce a single tone of motion so that a flute represents eight or twelve cells together, constituting a group of elementary organs.

The functions of the different tissues of the body are carried on, in some degree, by the disintegration and consumption of the tissue itself. The energy of muscle contraction is furnished by the decomposition of parts of the muscle itself. The same appears to be true of nerves, and is certainly true of brain cells, so that all sorts of brain action, including consciousness, involves the wear and tear of the cells themselves, and so demands and brings to them an increased supply of blood to furnish material for renewals and repairs. Even a sound made near a sleeping person, which does not wake him up, will increase the flow of blood to the brain. (See pages 517 and 815.) But the function of sensation or consciousness is further proved to be a mode of physical energy by the fact that it is one term in a series of physical actions, each of which is set going by one which preceded it, and upon its termination inaugurates another to succeed it. If sensation were simply a sort of ornamental function blossoming out from the other mental action, and never of itself doing any work, the case would not be so clear as it is. But, as we saw in chapter 70, the sensations are potent factors in the inauguration of motor nerve action. In fact, pleasurable and painful sensations (re-experienced through memory) constitute the entire force behind the will in purposive actions.

It was shown in chapter 70 that the formation of the will is followed by an efferent nerve current towards a muscle. Unless the will were itself a mode of nervous energy, this could not happen, since no new motion can come into existence except as the consequent of an antecedent motion. The will, therefore, is a mode of motion, and, by the law just mentioned, must be preceded and initiated by other motion. We found the will to be made up by, and to be, in fact, the resultant of, other energies called sensations; these sensations consisting of recollections of pleasure and pain accompanied by other sensations of ideas, or their recollection. The former comprise the more energetic and aggressive stimulations, and the latter act chiefly as modifiers in restraining or accelerating, and in selecting time, place and means. But, at all events, these sensations are genuine nervous stimulations, and are as certainly terms of physical energy as are the stimulations from luminous, sonorous or odorous bodies. Thus, whether we approach consciousness from the afferent side or the efferent side, we reach the same conclusion. It arises as a sequel to the expenditure of energy, and it transfers its energy when a will is formed, and when it is not, the sensation is turned

into heat. Thus, it is a term in a series of molecular physical movements, and is therefore itself a form of physical motion.

As observed above, our consciousness consists of separate sensations, each of which relates to a definite nervous action that preceded it. We have a sensation of an impression of the impact from a luminous body, another of a perception of what the body is, another of an idea of the cause of it being luminous, &c. Thus, the sensation is always in association with, and subsequent to, another mental act; and when it is called up in recollection, the recollection of its related mental act is apt to be called up too. This is more especially the case with objective sensations in their relation to their ideas and perceptions, the sensation of the idea and the idea itself, often appearing to us identical. But also in the case of subjective sensations, such as the feeling of hunger and plethora, sea-sickness, giddiness, feebleness, and the like, we ordinarily fail to disconnect the sensation from the nervous action which precedes it; but in this case the sensation alone is recollected, while the antecedent action is obscured, as a rule, although it may be brought out again in rare cases, as when a person becomes nauseated from the revival of a memory of excessive disgust. This would be a case of reverse action in the nervous machinery, such as we have observed in relation to illusions, &c. The back action of the nervous machine in the production of the nausea, reverses the action of the muscles concerned in swallowing, if carried to an extreme. (See page 611.)

There is no difference in principle between subjective and objective reactions. To the organs of sensation in the brain, all other ganglia and nervous machinery are objective, regardless of whether they are close by them in the cerebrum, or down in the medulla oblongata, or even in the great ganglions and plexuses of the sympathetic system among the viscera.

The distinction which thus shows itself between the sensations on one side, and the impressions and other nervous actions on the other side, indicates that their functions are separate, and carried on in separate organs; and that the former, although consequent upon the latter, are not merely subdivisions or incidents of them. We thus conclude sensations to be motions of matter, thus distinguishing that they are not properties of matter, for a property is a constant and stolid condition of a body, which remains until the environment changes the body itself. For example, a piece of spring-steel of a particular shape, possesses a property of elasticity, which, when the spring is snapped, causes it to vibrate for a time, until friction gradually changes the motion to heat. Elasticity is its property, vibration its function. The function of sensation comes upon stimulation, and goes as its activity is dissipated into heat, or communicates activity to other nervous ele-

ments, as nerves or ganglions. Like the vibratory motion of the spring, it may be regarded as the vibratory motion of a particular portion of elastic matter arranged in a suitable shape. Probably an instrument like an open flute would be a better simile than a spring. For the *form* of the cell containing the ethereal substance, whose motion is sensation, must govern the *form* of the portion of this substance which is, in each particular instance, detached and set off from the general mass. Form, in a vibratory mass, is of essential importance to the quality of its vibrations. It is of equal importance, to the movement set up in any sort of instrument or machine. As we have seen all along, the organs concerned in the performance of any sort of organic function, are subject to modification by the action upon them of the force by which they are operated, and this generally means a differentiation and development of the organ, increasing its facility and thoroughness of function. Examples of this are found in the development of the highly contractile muscle from inertly contractile protoplasm; of the ocellus from a pigment spot, and the eye from the ocellus; of the four bones of the ear from the columella, of wings from paddles, &c. Following this analogy, we may be assured that the function of sensation has undergone modification through the development of the material apparatus whose motion it is. If we have a mass of steel in a solid lump, it possesses elasticity, and if we strike it with a hammer, the hammer will bound off, and the steel itself be set to vibrating in a slight and subdued manner. If the shape of the mass be changed to form a rod, its elasticity causes it to vibrate in a different manner, and more freely, and at a smaller expenditure of antecedent force.

This sort of development has taken place in regard to organs of sensation. Undoubtedly those animals which have a better general development, also have more sensitive organs of sensation, and a greater number of them. They would necessarily become developed in approximately the same proportion.

Like any other function, sensation becomes more acute and vivid by action; so that the oftener the organ of a particular sensation is re-erected by recollection, the more real and vivid the recollected sensation of the image, idea or thought of any kind, becomes. Thus, if we wish to retain in memory a poem, an oration, the circumstances of an event, or anything of the sort, the oftener it is called up, the more indelibly does it become impressed; that is, the organ involved is stimulated to perform its normal function in greater force, with less expenditure of antecedent energy; in other words, with less effort. But there is an apparent exception to this in the very different effects ordinarily resulting in the case of recollection of highly emotional sensations. Extremely pleasurable sensations are made more intense by their frequent recall, not

only in regard to the vividness of the recollection of the incidents and circumstances leading to the original enjoyment in the first place, but also in regard to the sensation of the enjoyment itself. The more we dwell upon it, the more we enjoy it, and the happiness of one day becomes the happiness of a lifetime; as "a thing of beauty is a joy forever." But with grievous and unhappy memories the case is apparently different. While the recollection of the incidents and circumstances leading to an unhappy event do not fade from memory, and may be kept bright and vivid, the pain attending the recollection constantly diminishes in all well balanced and healthy people. The reason is, that sensations of pain indicate a state of inharmony or collision, in which one set of organs are in antagonistical relations with others, the two opposite sorts tending by their adverse actions to undo or neutralize each other. (See page 711.) It is the same process which was discussed in the last chapter under the title of inhibition. The organs of painful memories, being in a condition of inharmony with the other organs previously built up in the brain, the latter automatically by their activities tend to inhibit the former, and so gradually reduce their vividness, while the memories of the events themselves, so far as they may be considered without connecting them too closely with our personality, remain without being antagonized and inhibited by the others. The possibility of this sort of discrimination is confirmatory of the view here taken of the distinction between thought and sensation, and the existence of separate organs for the latter. If sensation were merely a part of the function of thought, it is difficult to see how it could be inhibited without inhibiting the thought itself. But here we have satisfactory evidence of the inhibition of sensibility by a gradual process operating upon principles essentially the same as those of the rapid process by which it can be made to take place in hypnotism.

When a grief or pain is overpowering, attention is forced to it, and it cannot be neutralized by the adverse action of the other organs. It becomes a dominant idea, and the subject becomes dejected and melancholy, perhaps insane.

Sensations of pleasure and pain are in one sense sensations of perceptions or comparisons. If we hear a wonderful statement of some things purporting to be fact, but which contradicts everything else we know, there is an automatic comparison between the alleged new fact and our standard organs, and since it cannot reinforce any one of them, it is rejected or inhibited as to its pretension to be true. So that although we afterwards remember the story, we fail to remember it as being true. A similar comparison automatically made in the case of stimulations that relate to things which intimately concern ourselves, at once settles the point whether they harmonize with the general run of

the former stimulations which made us what we are, or not. If they do, the sensations which arise as the sequel are pleasurable, while if they do not harmonize, the sensations are those of uneasiness or pain. In all cases the intensity of the sensation is in proportion to the number of our standard organs with which the new stimulation is compared, and the extent to which they disagree.

Self-Consciousness. From the foregoing it will appear that there cannot be self-consciousness in any single organ, because consciousness arises only as the sequel of stimulations, and no organ can stimulate itself. To really do this would be to originate energy from nothing. If it be supposed that energy communicated to an organ might pass from one part of such organ to another part of the same organ, then the second part would become a seat of consciousness of the first part, which would still not be *self*-consciousness, and would be equivalent to making two organs out of one. A sensory organ is the seat of sensation aroused by impact upon it of stimulation coming from without itself, either from an external or an internal sense organ. The environment of every sensory organ is composed in large part of other such organs, and the stimulation which one of these transmits to another, arouses in that other a sensation of a condition in the sending organ. The function of some of the organs is analytical; that is, receiving a compound stimulation, they split it up, sending its components in different directions. Other organs are synthetical, that is, receiving stimuli from different quarters of a similar or comparable nature, they allow them to come together in the formation of new combinations. The interactions of these stimuli constantly discharged from organs to organs, arouse alternately in every locality of the brain, sensations of the conditions in other parts. It is this mutual, rapid interchange of sensations referring to other parts, that gives rise to the sense of self-consciousness. We are conscious of action in first one part, then another; that is, one part is conscious of action in another alternately, and, doubtless to a certain degree, mutually; but no part is ever conscious of its own action. The stimulus which *enters*, differentiates or else re-erects the organ if it had been differentiated before, and as the differentiation or re-erection constitutes the sensation, the *amount* of the energy consumed in the process is its measure of intensity. The sensation is the modified continuation of the stimulus, and is the vibration of the ethereal substance belonging to the cells of the organ. During the continuance of this vibration, which endures for a moment after each wave of stimulation ends, the sensation endures. Thus, this motion of the cell which, considered as an object by a second person is a vibration, is to the person experiencing it a sensation. A sensation ends when the vibration dies out by the friction of its movement which is thus reduced to heat. It

also ends when it gives rise to an efferent current or shock to another organ, or enters into some combination in the formation of a will; and that same sensation will never be experienced again; but another very much like it may be experienced if another pulse of stimulation should be sent from the same quarter and strike the same organ. Or, if the receiving organ be again stimulated by the overflow of excitement from an organ with which it is related, other than the one from which it received its first differentiation, the effect is recollection, the physiology of it being the revibration of the ether of the organ in the same pitch, but in reduced amplitude. It is these revived sensations, that, entering into the combinations forming the will, give purpose to most of our voluntary actions. In order to have a continuous sensation or consciousness of one object, we must have a continuous flow of stimulations from such object. Thus, as long as we keep our eyes fixed upon an object, vibrations of the external ether reflected from the object, flash against the retina at the rate of five or six hundred trillions per second, and the current up the optic nerve is kept going continuously. But the moment we take our eyes off, the current stops, and if we continue to have any sensation of the object it is only restimulated memory.

It seems, then, that the motion of the sensory organ, which appears to the thought as simply a quiver of a subtile substance, appears to the feeling as a sensation. This is, however, after all only such contrast as appears between the different senses, such as a touch and a taste of the same object, both perhaps effected through the same tongue, or sight and sound, or even between two tones, as red and blue, &c. It is as impossible to tell in what way these differ from each other, as in what way they differ from thought. All of them considered as objects are only various modes of molecular motion of a material substance.

The only knowledge we can get of a sensation is to experience it. There is no possible way in which we could convey to a blind man an idea of green. This is one of our sensations, and is a sequel to waves of ether $\frac{1}{50\,000}$ of an inch in length. But if we should tell that to the blind man, what idea of green would be conveyed to him? Even if we knew exactly the sort of movements which take place in the cell itself when such movements are sensation, we could not thereby get the slightest idea of the nature of the sensation. If two persons each look at a green leaf, and each says that he experiences the sensation green, neither one knows that his sensation is like that of the other person. If A cannot *be* X, he cannot experience sensations that are the same as those of X. Sensations can be described only in terms of sensation, and if X appears to be like A, the latter may describe his own sensations by telling X they are like his. They may be supposed to be similar, but they are necessarily not precisely alike. Every sen-

sation is a result of the function of an organ peculiar, personal and unique. The conscious personality of every individual is simply the mass of his sensations considered as an aggregate. The only explication or interpretation of any problem possible to any person is the association and comparison of such problem with his already erected standard internal sense organs. This is not possible until the reactions from the problem stimulate sensations in his brain. If the problem as a whole cannot arouse sensations that are comparable or assimilable in the man's brain, it is picked to pieces, and separate sensations of the different pieces are introduced. But when the problem is a sensation to begin with, as, for example, green, it is already introduced and compared with standards of green previously in the brain. It neither admits of nor requires any picking to pieces, for it is already comparable with the standards, and is of as low terms as possible. If the sensation is compound, and a reduction is required, the pieces are separated, and each dispatched to its own place; but each piece, after such reduction, is still a sensation, and cannot be reduced to anything more simple.

If we compare what is said here with the conclusions reached on pp. 848, 849, we shall perceive that a simple sensation is of a more elementary nature than an axiom. An axiom is defined to be a self-evident truth. Truth is simply the correct reflection of the environment in consciousness (page 858), and therefore is sensation. A self-evident truth is a perception, which consists of the association and mutual support of two or more sensations. A perception is a new compound sensation formed by the superposition, one upon another, of two or more simple sensations. An axiom as defined, therefore, is a compound sensation, and the original sensations which underlie it are more simple than it is. A simple sensation is not self-evident for the reason that it cannot be its own subject, as pointed out above, in considering the question of self-consciousness. But a single sensation is absolute truth. It neither requires to be supported by evidence, nor is it competent to receive such support. A perception because it is often an attempt to construct a whole picture from partial and limited materials, may be far from truth. But the sensation is the absolute mechanical equivalent of the antecedent energy consumed in its production. It is the ultimate fundamental element in the conscious personality, and it cannot be reduced or accounted for *in the personality.* Any further reduction or analysis of it disintegrates the personality. Red in the personality is only red, nothing more nor less. Its antecedent form of energy lies outside of the person, and a further pursuit of it takes us across the boundary which separates the person from his creative environment. It thus becomes obvious why there can be no subjective simplification of sensation. It is itself the lowest term of the subject.

The axiom is the lowest term of perception that can exist, as perception. Analyze it further and we get no longer perceptions but their antecedent elemental sensations. The sensation being simple it cannot be analyzed, but traced to its antecedent cause we have no longer sensation but another form of molecular motion.

If all bodies were of a uniform nature, constitution and form, there is no reason to suppose that there would be different modes of motion. When a cannon is discharged, the force of the explosion drives the ball in one direction and the gun in the other. But the characters of the movements of these two are in striking contrast, owing to their difference in form, mass, &c. So the same wind causes the fluttering of the flag at the mast head, the whistling and roaring music of the rigging, and the undulations of the briny waves, the differences in motion obviously due to the differences in the bodies moved. And in each case we know that the several motions represent an amount of energy abstracted from that of the moving wind, the force of which is reduced by that much. So when we see a molecular motion outside of the body setting up a different sort of motion inside of it, we are justified in concluding that the cause of the change in the form of the motion is the difference in the form of the body moved. In other words the reason why a peculiar undulation of ether sets up the motion called red, is because the small quantity of ether in the brain cell is under different conditions from that outside. And the further deduction is legitimate, that when protoplasm is organized into the peculiar forms of nervous and ganglionic tissues, it is susceptible to the motions called sensations; and further still, that the action of external molecular energy upon protoplasm tends to thus organize it.

It is easy to see that there are great differences in degrees of sensibility. The tissues involved, like those involved in muscle movement, are wasted by the exercise of their function, and are repaired by renewals from the blood. As in the case of the muscles too, the renewals may exceed the losses and the tissues grow into better working conditions. This, as observed in the case of the muscles, is no doubt promoted by the greater energy that characterizes the chemical reactions when the elements are in the *nascent* state, as they are after being forcibly freed from a former combination. (See page 498.) It is also promoted, as pointed out by H. Spencer, by an increase in the capacity of the blood vessels, which takes place on account of the extra amount of blood demanded and forced through them during continued and steady moderate work, by which increase the quantity of blood delivered will continue to be greater, and thus the organ so nourished gain in size and force. The same law of gain from being operated, governs in the case of the nervous and brain cell tissues, as we all know by experience, and

by observation of the increased facility of brain action generally, including the sharpening and quickening of the sensations by use. The fact of such improvement in sensibility and therefore in consciousness by use, puts this class of functions and their organs upon the same physiological basis as the muscular, vascular, visceral and osseous systems and argues for them the like evolution and specialization from the most elementary beginnings. Judged by these analogies, we should be led to suppose that the essential basis of sensibility resides in a diffused and nebulous condition in tissues both animal and vegetable, and possibly in elemental bodies, as phosphorus, perhaps. The conception is, that sensation is a particular tone or scale of tones of some sort of motion of the *ether.* Such motion takes place in portions of the ether, of a certain density, that are cut off from the general mass and shut up in cells of dense matter of particular form and size. Whenever matter is organized in such a way that it contains such molecular interstices, the contained ether, if of the requisite density and agitated by stimulations of a proper tone, becomes sensible; that is, the motion set up in it is sensation. In unorganized or poorly organized bodies in which there are few or no nervous pathways, we may suppose that the stimulation from the outside is largely consumed by friction in getting at the enclosed spaces so that the agitation set up in them is in small amplitude and of a feeble and subdued nature. In the lowest organisms, such as amœba, monera, &c., the sensibility is confined to such as can be aroused by touch and light, and is scattered through the tissues. In plants it is also confined to touch and light, but to a certain extent specialized in the roots and leaves. The forming and shaping of the spaces which in organized bodies become cells, are due without doubt to the action of the external energy, and the tendency of this action would be to develop these organs in the parts most accessible to it. Thus it is that cells sensitive to touch are found in the roots of plants, and that those sensitive to light occur in the leaves. The sensibilities become, in all organisms (to the extent to which they occur), elements for the direction of the motor energies—will formers. This puts them in an intermediate relationship between the external energies that cause them, and the motor parts whose action they govern, and leads to the aggregation of their cells in ganglions in intermediate positions.

At first there is no separation or distinction between the functions of sensibility and kinetic impression. By kinetic impression, in this connection, I mean those impressions made upon bodies both organic and inorganic, by radiant and other forms of molecular motion, whereby molecular changes (other than sensibility) are wrought in the bodies. Examples of this action are given in chapters 42 and 43. The chemical and other physical changes produced by light and heat in inorganic

bodies, we commonly suppose are not accompanied by sensibility (although it would be difficult to prove it). But at the other extreme, in the highest organism, man, we find precisely the same rays of light and heat produce these chemical and other physical effects and at the same time set up sensation. This shows that between these extremes there has occûrred an evolution of organs so differing in character, that the energy which results in the organism from the impact of the suns rays on the outside, is split up, part of it arousing sensibility and the rest effecting other sorts of changes in brain cells and other tissues. If a beam of light strikes the face it tans the skin, a chemical effect; it also raises the temperature, a physical effect; it contracts the pupil of the eye, a mechanical effect; it excites the rods and cones sending currents into the brain which subdivide, some going to the organs of sensation and producing a sensible effect; while others rearrange organs in the internal sense region and produce a mental effect. A different pair of sensible and mental effects are also produced by currents sent to the brain from the heated skin, a secondary effect. Now these various effects of the apparently simple energy are not exhibited until various sorts of organs have become differentiated. But this differentiation begins and makes progress before it shows itself on the outside, and the distinction between impression and sensibility may become sketched out further down in the scale of being than we are apt to imagine. All intermolecular spaces are filled with ether, and its agitation by any external force has some effect upon the body enclosing it. Such effect under certain conditions is in the direction of organization, so that we may say that ether ensconced in denser matter and subject to the influence of external energy, furnishes conditions which include the potentiality of sensibility as well as impression. Both of these functions are performed distinctly, as it appears to me, in all animals possessed of ganglions and nerves, and especially all that exhibit signs of pleasure and pain; and among these may be included all that make an effort to get food. We have evidence of impression being expanded to thought in molusks and articulates, and certainly whenever the memory is exhibited it is sufficient evidence that this differentiation has been accomplished; for recollection *is* thought. In all probability there has been a a *pari passu* specialization of thought, and sensibility from mere impression, so that we shall find an approximate correspondence between the two wherever they occur; but not necessarily an exact one, because it is possible for the development of either to proceed in a limited degree independently of the other.

As there is a progressive development of sensibility from lower to higher organisms, so there is reason to believe there is a different degree of it in different tissues of the same organism. In the inverte-

brates there appears to be by no means so complete a centralization of the function as in even the lower vertebrates, while in the mammals and man it is generally assumed that it is concentrated exclusively, or almost so, in the brain. In the brain are located the chief centers of memory and thought. The greater part of our consciousness is made up of sensations of thought and memory. The organs of such sensations are probably located in the neighborhood of the organs from which they receive their stimulation, that is in the cerebrum. So also, the organs of direct sensation for sight, smell, taste, hearing, and touch by the tongue, have their organs of sensibility in the brain.

It has been pointed out (page 270) that the process of differentiation is one in which one portion of an organism, or organ, is selected by the kinetic agency to receive the bulk of its stimulations, while the rest of such organism remains without attention or stimulation of that sort, the effect being that such specially stimulated portion becomes improved in its function, while the neglected portion loses such responsive pliancy as it may have possessed. Supposing that sensibility was originally included with impression, and that its seat was in the locality in which the impressions were made, that is, in the external sense organs, the process of differentiation has separated the functions, and while allowing the kinetic impression still to pass through the sense organ, analyzes it after it gets through, one part going to form an organ of sensibility, and another to form an organ of an idea. That such differentiation might in the course of time become perfect and absolute, is proved by the example of the function of contractility, which, in the lowest organisms, belongs to all the parts alike, but which in the higher has become greatly varied, some parts, as certain muscles, being extremely contractile, while others are inertly contractile, and still others, as nerves and bones, not contractile at all. That sensibility may have likewise become separated from its original associations in different degrees, is antecedently probable, and appears to be indicated by the facts.

There are two sides to the body, each of which is exposed in its own way to the influence of kinetic agencies, namely the inside and the outside. We are but little conscious of the operations which go on in the inside, and of many of them we are not conscious at all. This means that such sensibility as accompanies these operations has its seat in the plexuses and ganglions of the sympathetic system, rather than in those of the brain. The great semilunar ganglion and solar plexus situated behind the stomach are no doubt centers of sensibility as well as governors of visceral motor action. The solar plexus is sometimes called the "cerebrum of the abdomen." This is a case of local self-government. Although there is nervous connection between these centers and the brain, still except in special cases there is no transfer between them

of either motor control or sensation; so that *we*, or the general personality represented in the brain, have in general no sense of what sensibility there is in those centers. But if something extraordinary happens down there, as a blow upon the pit of the stomach, the sensation aroused there overflows up to the brain and agitates the sensory centers there. There are a number of subordinate plexuses which are tributary to the solar plexus, and which, perhaps, act as brains for the special organs with which they are in association. Thus, as we go away from the central controlling ganglions, we find sub-ganglions in special control of smaller districts and subject to the central authorities in all matters that require the co-operation of other parts. Likewise we may suppose that sensibility thus subdivides, and that the action of the smallest collections of nervous elements are regulated by small and special sensibilities, having their seats in the same ganglions. It would seem therefore that the brain is not the center for the *special* control of the vegetative functions, and by analogy may be supposed to be not the center for all the common sensibilities of the vegetative system; and by no effort can it either control it by the will or find out its condition through sensation.

With the outside of the body the case is different, although the principles are the same. The brain belongs to the outside in a special manner. It is developed from the outer skin in the first place, and the sense organs and muscles are likewise products of the first and second layers[1], the whole constituting the outside half of the body. The differentiations which have concentrated sensibility in the brain, place it in a far more intimate relationship with the outside than the inside, and far less, in proportion, of the original sensibility remains to the tissues of the outside. As observed above, all the sense organs located about the head have their ganglions inside the cranium. If any sensibility remains not concentrated in the brain, it is in the ganglions of the spinal cord. These ganglions constantly change afferent stimulations into motor ones, and do this when disconnected from the brain. But unless they are connected we get no sensation of either the afferent or efferent stimulations. Yet it is maintained by some writers[2], that the sensibility is there, but is as if it were the function of another person, because it is disconnected or "inhibited" from the rest of the personality. We have seen that there are direct connections between the spinal ganglions and the cerebrum, from which it might be inferred that the brain has assumed the function of sensibility in part at least, for these localities. Whatever stimulation there may be in the extremities or anywhere on the skin, we are liable to become sensible of it, and if it be at all unusual, as a scratch, bruise, blow, &c., we are pretty sure to

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[1] See table X, page 64. [2] See G. H. Lewes, Problems of Life and Mind.

feel it. There is nothing violent in the supposition that the whole sensibility of the skin has been transferred to the brain, leaving only motor reflex functions in the ganglions of the spinal cord. On the other hand it is not inconsistent with the dynamic theory to suppose that some sensibility still remains in the spinal ganglia, since, wherever the seats of sensibility now are, they have been formerly diffused to various parts of the body, and the question whether their removal to the brain, which has gone on in the past and is no doubt still going on, is yet complete or not, appears to me to be of subordinate importance. If we do not admit the principle of differentiation and transfer at all, then we should have to hold that sensibility still resides equally in all the tissues, which is obviously not so. If we do admit it the conclusion follows that it *may* all become transferred.

It was observed above that sensation is motion in different tones, that is, that unlike sensations are different rates of movement. This applies obviously to different tones that belong to the same character of movement. But there may be two modes of molecular motion, the undulatory like that of light, and the pulsatory like that of sound; so that probably we may have two sensations at the same rate or pitch, totally differing in character, as sound and warmth. There may be other peculiarities in vibratory motion besides these, which vary our sensations. The senses of smell and taste and the muscular sense have peculiarities which appear to require a different classification.

The conditions which produce sensation are those consequent upon an arrest of motion, and as motion cannot be quenched or annihilated, all that is meant by "arrest" is its change from one form to another. The differences that occur in sensations are due to differences in the form of the motions arrested, and we have a vast number of sensations because there is an equally vast number of tones and various modes in which bodies move.

We often speak of heat being the result of friction and of being a mode of motion. This is true, but the idea we usually associate with the expression is decidedly mixed. The friction of two bodies rubbed together produces a rise of temperature in the bodies. If we touch the bodies, the state of their temperature, which means the rate of their molecular vibration, sends an agitation to the brain which is there arrested by a new friction and given the new form called heat. Thus we have friction representing arrested energy with a rise of temperature of so many degrees as its measure, in the environment; and we have friction of arrested energy in the brain measured by a quantity of *heat*. Thus the *heat* is sensation and its seat is in the brain and *not* in the external object of high temperature. I know I am insisting here on what everybody knows, but I am sure but few realize that heat is a motion of

their own, and not a motion of the hot body; and that it is in fact *a part of their own minds.* In like manner we say we *have* a sensation of red or of a sound, &c., as if an object we looked at were red, or the sound pertained to the sonorous body. These are also parts of our minds. We do not have a sensation *of* red, but we have a sensation *red*, and it is a sensation of ethereal undulations of a particular rapidity and length. So white, cold, hot, bitter, sweet, sour, &c., are motions of our own brain, and do not belong to objects in the environment, although they are the sequels of the motions of such objects.

The intensity and quantity, then, of any sensation is in proportion to the friction of the incoming stimulation that represents the amount of it that is arrested and reduced to the new form of motion, sensation. The process is generally accompanied by an increase of temperature in the brain tissues, which increase may give a secondary sensation of heat. This rise of temperature is due in part to the arrest of tones of stimulation which do not arouse sensation, and in part to the additional quantity of blood which is thrown into the brain upon every stimulation, which establishes a temporary center of attention there. (See page 670.)

Where the same stimulation continues to be monotonously repeated for a considerable time, sensation of it ceases after a time, in spite of the continued action of the stimulus. If the organs upon which the stimulations play, were not wasted by the action upon them, the consciousness would continue. But they become unable after a time to be moved, and go to sleep, and although they are doubtless soon repaired, and although the stimulus keeps on, they are apt to sleep until the stimulus stops and then a sensation is again aroused. Thus a person sitting quiet in a mill will be put to sleep by its drowsy hum, but if it stops, he will awake with a start. So, as observed by Bain, a watchmaker is not aware of the continuous ticking of his clocks, but would be quickly startled if they all suddenly stopped. We are strikingly reminded by this action, of the performance of the galvanic current induced in a secondary coil upon the opening and closing of a primary, as shown on page 332. We are probably not entirely unconscious of the monotonous sound even when we seem to be, but keep a sub-conscious reckoning of it as we do our natural sleep. After waking we have some sort of notion whether the nap has been long or short. So the absence of sensation of sound during stillness is different from the absence of sensation produced by monotony. Yet we seem to have a sensation of silence as if it were a positive quality.

The sensation of black as a color is also due to the same principle. White, yellow, red, &c., are real sensations originating in real motions of ether in the objective environment. But black is simply silence

as to color, and affects us only by contrast or stoppage of real sensations.

CHAPTER LXXXIV.

THE MIND.

The mind consists of three forms of nervous action; viz., consciousness, thought, and reflex action. The nature of all these has been discussed in former chapters. They are all forms of motion and not things. Reflex is the term applied to nervous action which does not involve either consciousness or thought. This action is explained in chapter 59. It was shown in chapter 75 that much of the brain action is performed in unconsciousness, and in chapter 82 it was shown how there can be a suppression of sensibility as to nervous actions which usually give rise to vivid sensation. It was pointed out in chapter 71 that emotions, that is, sensations strongly involving the personality, are always dominant elements in the formation of the will. Without them there would be no will, and if they were different the will would be different. The processes of thought, reason, &c., that accompany the emotions in the formation of the will, only modify and regulate the energy, but furnish only a small part of the original impulse. Thus sensations are in a measure separated from thoughts and furnish independent nervous stimulations, the result of the movement of their own peculiar tissues.

These three varieties of motion all belong to the same species and are physiological equivalents of the physical energy expended in their creation. We have no difficulty in perceiving the purely mechanical nature of reflex action, and even of perception, reason, will, and the processes of thought generally. They are all seen to consist of the interactions of the purely physical nervous energies, which as automatically work out a result as leaven does in a batch of dough. Even sensations considered objectively are seen to belong to the same class of phenomena and to be potent and active forms of the same energy, alternately consequent and antecedent in many series of movements. It is only the subjective aspect of these that is irreducible, because its reduction must consist in the disintegration and destruction of the inquiring agent itself, namely the sensation, as if a man should dig out his own eyes for the purpose of looking at them. [See last chapter.]

It has been pointed out that one-fifth or more of the blood goes to the brain, and the rest goes to the stomach, muscles, &c. The functions of the blood relate to purely physical operations, and the large proportion consumed by the brain show its functions to be physical. It is,

therefore, to be classed with the stomach and muscles as one of the physical organs. It matters not what sort of a mental process goes on, we observe that it requires in every case the expenditure of blood. If we take a run of a few rods we find the circulation of the blood greatly accelerated, which means that the violent exertion has rapidly oxidized the tissue involved, mostly muscular and nervous. But an acceleration of the circulation may take place through purely mental excitement. Horror, fright, anger, rage, and all the more violent emotions instantly increase the circulation, when it is obvious that the expenditure of tissue is that of the brain alone. The fact is the same with all the milder emotions, love, admiration, hope, joy, &c., to a less degree of course. All the intellectual operations in like manner wear out brain tissue which has to be replaced from the blood. The heating effect of mental work and worry caused by an extra flow of blood is recognized in the slang threat of "making it hot" for an antagonist, and the designation of the witness' chair in legal slang as the "sweat box." It is also seen in exciting mental games as of chess and cards; in the latter, however, more especially when accompanied with considerations of pecuniary value arousing emotions. In all sorts of gambling and speculating the waste of brain tissue is great. The difference in the circulation of the blood between sleep and a state of wakefulness, is of itself enough to show the most passive sort of mentality to be a state of physical action, the mere attention of wakefulness, however passive it may be, requiring a greater expenditure of blood than is necessary in sleep. The brain is a machine by means of which the forces in the environment operate the muscles of the body. The movement imposed upon this machine by these forces constitute the mind, and the mind is therefore a necessary link in the chain of causation beginning in the sun and elsewhere, and ending, so far as we are concerned, in the movement of leg, arm, lip, tongue, eyelid, &c. The brain is divisible into two parts, much the larger of which is used in *forming mind*, while the smaller motor part is driven by the mind *when formed*. If a machine gets damaged, broken, or worn out it fails to turn out a satisfactory product, and so as we have seen, when the brain is damaged its products are imperfect or fail altogether. If the part of the brain operated *by* the mind gets out of order, the force of the mind cannot drive it. This happens in cases of disease in which the subject has full sensibility without the power of executing a will, as in cases of defective cerebellum, &c. (page 623.) But if that part of the brain is diseased whose function it is to *form* the mind, then the *mind* is erratic, and the subject is insane. A common opinion is that the mind (or soul) is an intelligent Person to whom the brain is a rather unhandy and clumsy tool, disappointing and exasperating at best; and that when the Mind

is no longer under the compulsory penance of using it, it will be able to get along far better. Some advocates of this opinion say that the soul is always sound and sane, but that when the brain is out of order, the work done through it is of an abnormal nature.

By remembering that only a small part of the brain is *used* by the mind, viz., that part devoted to motor functions, we can readily separate the resulting actions and distinguish that some of them are indeed due to a bad apparatus in the hands of a sane person, as in the cases of animals deprived of the cerebellum. But we also distinguish the cases in which the person and the purpose he forms are insane, when there is no lack of ability to carry the purpose into execution. In the case of the insane woman (fig. 375) who had lost the civilized part of her *mind-forming* brain, it is easy to see that the mind itself was defective, and why it was.

If a man should attempt to build a fence, in the absence of important tools, as a saw, a spade, and a hammer, he would substitute some other tools or do without. He could dig holes with a stick and lift the dirt out with his hands; he could drive nails with a stone, or in the absence of nails, he could tie the boards to the posts with wire or bark; in the absence of boards he could lay up a worm fence of saplings or rails; in the absence of these he could erect a barricade of "brush." In any event the thing he made would be a fence of some sort. It would not come out a chicken coop, a wheel-barrow, or a foot-bridge. This is a sane purpose behind poor tools.

The development of bees, although involving mental results, is a purely physical process and depends upon conditions of food, and the cell or nest in which the development takes place. Compare the difference in development between a worker and a queen. They are both born from the same sort of an egg and the difference which arises between them is created by difference in treatment. The eggs from which the queens are hatched differ in no respect from those which produce workers, but they are deposited in a different sort of cells. These cells are larger; their form is not hexagonal as the others are, but an oblong spheroid, and they are not built among the other cells but attached to them across their external openings. They stand vertically with the mouth down. Four days after the egg is laid in one of these royal cells the grub or larva is hatched. This royal worm is fed by the workers on a peculiar, rich jelly of an acid character which is elaborated in the stomach of the worker. In about five days the royal maggot or larva commences forming a web about herself which she completes in 24 hours. The cell is closed up by the workers. Inside the web or cocoon the maggot is developed into the pupa, and finally becomes a perfect queen in about 17 or 18 days from the time the egg is first laid.

Her cell is then more securely fastened up by the workers and she remains imprisoned until the departure of the reigning queen with a swarm, or some other casualty makes it necessary to release her.

The development of the worker from the egg to the larva is just the same as in the case of the queen. In about four days it assumes the form of the maggot. It is then fed for a time upon the jelly-like food, and after that upon bee-bread, which is composed of a mixture of pollen and honey. At the end of about eight days from the deposit of the egg, the larva has grown so much as to fill the cell. The workers then close up the cell and the worm undergoes its metamorphosis into the pupa and thence into the perfect fly, during the next twelve days. Its whole development takes about 20 or 21 days, when it cuts away the cover of its cell and comes out.

Now it is proved by observation and experiment that if maggots hatched from the worker eggs be transferred from the worker cells into royal cells, and fed and treated in the same way as the royal maggots are usually fed and treated, they will develop into queens instead of workers. The full significance of this is very great. It proves that first, the development of the form and structure of the insect depends upon the quality of its nourishment and the size and form of its environing case. The development of the queen includes the greater elongation of the abdomen and formation of two ovaries in it for producing and holding the eggs. The development of the worker requires three or four days more time, but instead of ovaries there are formed the pollen baskets on the hind legs, and the abdomen is shorter than in the queen. Second, the instincts of the insects agree with, and without doubt depend upon, these peculiarities of bodily form. The queen could not gather honey, nor the workers mature the eggs for the next generation since they have not the construction necessary for such functions. It is a perfectly legitimate conclusion therefore that in this case both the physical and mental make up of the animal depends exclusively upon physical causes. The operations of the bee are governed through its *mind* whether it works in consciousness or not; and the origin of the mind and its actions are in principle the same as in all animals.

Various circumstances occur in the life history of all races, including man and the individuals composing them, to fix their physical structure or to modify it as the case may be; and whatever it may be, such structure is as inevitable a result of the operations of its environment upon it as is that of the bee; and the functions which are destined to be performed through it are equally as fixed and inevitable a result of the further operations of such forces on such structure. We do not expect to "gather grapes of thorns or figs of thistles."

In all of our so-called mental or psychical processes, especially those

of a complicated nature or of rare occurrence, we are conscious of more or less delay before a conclusion is reached. If the ether of our nervous and cerebral tissues were anything like as nimble and responsive to the impact of force as is the hypothetical ether whose undulations arouse in us the sensation of light, the time required for an external stimulation to pass through our nervous and cerebral apparatus producing sensation, perception, and finally expression, would be so short as to be immeasurable. But the material of our nervous system has no such mobility as that of the free ether, and measurable time is required for all our mental processes, even those which are most habitual and the nearest being frictionless. The time required is greater in some persons than in others, and in the same person it is greater for some sorts of stimulation than for others; it is usually shorter with women and longer with children than with men. The time is shortened by practice, habit making the tissues concerned more mobile and responsive to the stimulation. According to experiments of Prof. Exner, the usual time required for a stimulus to produce a response in muscular expression is for touch sensations about one-seventh of a second; hearing, one-sixth; sight, one-fifth; taste, from one-sixth to one-fourth of a second. The differences are due to the different lengths of nerve to be traversed, and the different activities in the co-ordinating ganglia which lie between the afferent and the efferent nerves. The sight ganglia appear to be slower in making up their co-ordinations than the other ganglia, since it appears that although their nerves are the shortest, the time they require in the aggregate is longer than the others, except taste. After making allowance for the time occupied by the stimulation in traversing the nerve up and back, Prof. Exner found that it took the ganglia of sight from the one-twenty-first to one-eighteenth part of a second to turn the stimulation from an afferent to an efferent current, the action being the closing of the eyelid after a sight stimulation. The more complex the object seen, the longer it takes to accomplish the co-ordination; the fact being that a complex object is in reality several objects, and sight stimuli are, therefore, usually less simple than those which affect the other senses. In these experiments when the co-ordination was complicated by presenting two different stimuli at the same time, one of which was to be ignored and the other responded to, the hesitation became from twice to four times as long. Of course the general drill of education furnishes better equipped ganglions for unexpected stimulations. In an old man of 76 of an inactive mental habit a certain stimulation took almost a whole second for its co-ordination. After six months' practice the time was reduced to less than one-fifth of a second. Romanes mentions the case of Houdin, the great conjuror, who became so exceedingly rapid in absorbing and condensing sight stimuli, that on one occasion he repeated

the names of all the books in a library after a single momentary glance over the titles on their backs.

It is evident that the greater the number of stimuli which assail the brain at the same time, the greater is the number of ganglia that are involved; and habit and practice being equal, the greater the time employed, the greater the friction, the more vivid the consciousness of the process and its results, and the more intense the pleasurable or painful emotions which may happen to follow. In reflex actions where the stimulation is simple, the friction is at a minimum and not sufficient to arouse a consciousness, a certain amount of time is nevertheless essential to produce the result. Where the stimulation creates perception and arouses consciousness still more time is required. Where there are several stimulations of diverse and perhaps antagonistical nature, the time may run into hours or days, during which the ganglia involved are undergoing constant readjustments, the attention is strained and (ordinarily) consciousness is at a high tension.

In what has gone before I have set forth what appears to me to be the logical conclusions in regard to the nature of mental phenomena. It will be profitable now to contrast these conclusions with radically different ones reached by some of the most renowned thinkers. And first, I shall quote from Prof. Huxley's lecture on Animal Automatism, delivered at Belfast, in 1874, and a lecture on Sensation, delivered March 7, 1879. Then I will quote the views of Prof. Bain.

Prof. Huxley says in "Animal Automatism:" "It is quite true that to the best of my judgment the argumentation which applies to brutes holds equally good of men; and therefore that all states of consciousness in us, as in them, are immediately caused by molecular changes of the brain substance. It seems to me that in men as in brutes, *there is no proof that any state of consciousness is the cause of change in the motion of the matter of the organism.* If these positions are well based, it follows that our mental conditions are simply the symbols in consciousness of the changes which take place automatically in the organism; and that to take an extreme illustration, the feeling we call volition is not the cause of a voluntary act, but the symbol of that state of the brain which is the immediate cause of that act. We are conscious automata endowed with free will in the only intelligible sense of that much abused term, inasmuch as in many respects we are able to do as we like, but none the less parts of the great series of causes and effects which in unbroken continuity composes that which is, and has been, and shall be, the sum of existence."

The italics in the forgoing are mine and mark the passage to which exceptions must be taken. It is radically wrong itself and being a fundamental proposition it leads to a brood of other errors. The nu-

merous phenomena of unconscious brain action pointed out in chapter 75, make it extremely easy for any one to conclude that consciousness is a sort of ornamental function, nice on some accounts, but productive of such a frightful lot of misery as to render it an even thing whether we should not be better off without it, especially since as a business function it appeared to cut little or no figure. But the fact is, as has been pointed out, consciousness *is* a business function of the highest order. I believe that all our actions, except those exclusively reflex, are dictated by "states of consciousness," or as I prefer to express it, sensations. Even in somnambulism the subject is careful to avoid danger, and he must do it from the force of habit established while he was awake to sensation. But our waking actions are manifestly dictated with reference to their probable effects on us in painful or pleasurable sensations. (See page 771.) What is it that induces a child to handle a pretty coal of fire just once, and ever afterward induces him not to? What is it that enables the majority of people to resist the fascinating impulse to caress a buzz-saw?

Where Prof. Huxley says that the "*feeling* we call volition is not the cause of the voluntary act," he is right, but unfortunately this is not an "extreme illustration." It accords with what is said (pp 760-763) in regard to the distinction between the will and the sensation of it which supervenes *after* it is formed. But we are to remember that the will is on the motor side of brain action, or at any rate on the boundary line, and is a part of the mental action inaugurated by the mind. The sensations which run it are on the other, the afferent, or mind forming side, and this *feeling* of a volition formed, does not get around to that side until after that will has been formed and perhaps executed. Of course it takes no part in the formation of *that* will, but becoming incorporated immediately with the other sensations which go toward the formation of *mind*, it may have an influence in subsequent formations of the will. Thus clearly we must distinguish between the sensations which precede and form a will, and the sensation which succeeds and informs us that such a will has been formed. If in walking you cast your eyes down, they may watch the motions of your feet without interfering, the sensations they convey being those of a spectator and subsequent to the fact; but if you see an obstruction, *that* sensation is antecedent to a will which causes the feet to move so as to avoid it.

We will now examine some passages in the lecture on "Sensation," before alluded to. Prof. Huxley calls attention to the obvious truth that the terms we apply to smell, such as musky, fishy, balmy, &c., relate to our sensations and not to the odorous body. Muskiness denotes nothing but sensation, is a mental state and has no existence except as a mental phenomenon; and it is as absurd to suppose it resides in a plant

or other body, as to suppose pain resides in a thorn bush when a thorn pricks the finger. The same is true of other sensations. Lavender-smell, clove-smell, garlic-smell have no existence except as states of consciousness. It is then explained that smell is due to the exceedingly attenuated particles of the odorous body that are thrown off into the air and carried by it into the nasal passages, where it excites the organs of the Schneiderian membrane, and sets up a nerve current into the olfactory lobe and cerebral centers of smell. (See chap. 49.)

Following observations like the foregoing, the lecturer goes on to say: "None the less however, does it remain true that no similarity exists nor indeed is conceivable between the cause of sensation and the sensation. Attend as closely to the sensations of muskiness or any other odor as we will, no trace of extension, resistance or motion is discernible in them. They have no attribute in common with those which we ascribe to matter; they are in the strictest sense of the words immaterial entities."

I agree that sensations are immaterial. All forms of *motion* are immaterial, whether they are movements of brain, or limbs, or cannon balls, or planets. But they are not entities if that word means beings or things. Of course none of the properties of matter are found in modes of motion, whether we speak of the molecular motions of radiation considered objectively, or the representatives of these motions in the sensations light and heat. Both the objective and the subjective ways of considering sensation were discussed in last chapter, and need only to be mentioned here. Considered objectively we have the same circumstantial evidence that sensation is a mode of motion, that we have that it is a mode of motion in a hot body that gives us the sensation heat. That is, the oscillations of the hot body are entirely comparable in principle, though not in species, with the vibrations they are instrumental in setting up in the brain, and for want of two names and a keen appreciation of their distinctness, we commonly call them both *heat*.

If we attempt to get any better insight into the machinery of sensation from the subjective side, and try as we do in objective cases to get two or three different views of the same sensation for the purpose of comparison, we find after every effort, that we have simply revived in memory the sensation we are trying to investigate, and so at last we get back to the starting point and find that the sensation of a sensation is simply a repetition of the same sensation. As sensation is the only instrument we possess for becoming acquainted with anything, even a sensation, all our explications must be in terms of sensation at last. We can explain one only by a comparison with another. (See chap. 83.) Whether a sensation feels to us like a motion of matter depends on circumstances, and on what we should imagine a motion of matter should feel like, no

two of us probably having the same idea of that. The impact of a violent sensation does convey to us the impression of physical motion. We feel stunned by a very loud sound, and we say of a very bad smell, it is enough to knock one down. We also feel dazed and stunned by a sudden piece of bad news. If we were not allowed to experience the sensation of sound before reaching adult age, I think the sensation would appear to us very different from what it now does, and would contain a large impression of physical agitation. We do not know that such impression is not all there is in the sensation as experienced by the simplest organisms, Cœlenterata for example. The tones of motion which give us the sensation of sound are those of such rapidity that a definite sensation of one stroke has not time to occur before the impact of the next. The tones below those made by 16 strokes to the second, appear to us simply so many detached blows of a ponderable body, while such idea is entirely eliminated from those above that pitch, an effect due solely to a mechanical cause. In the case of heat and light the principle is the same, but exhibited to a much greater degree, their pulsations being almost infinite compared with those of sound. Where the pulsations are, so far as our sensory apparatus is concerned, practically superposed upon each other, the effect may be compared to a pressure rather than a blow, in which case the different sorts of sensation would represent different sorts and degrees of pressure. Now we could not possibly have any antecedent notion of what we ought to consider as a "trace of resistance or motion" in a sensation. The manner in which the sensation behaves may for aught we know be precisely that which should indicate to us motion of the particular sort of matter involved. Extension we do not look for in sensation since it is not a thing or substance any more than is the motion that gives rise to heat and light. But where any sort of phenomenon has a beginning and an ending in time, it is certainly not an entity, but the motion of something. The very terms beginning and ending imply motion.

We often fail to recognize the difference between the sensation and the objective movement which produces it. We are very apt to think of *light* for example as objective, and imagine that our sensation of light is something else and different, whereas the fact is, that light is the sensation itself. Various degrees of heat and various tones of light, as red, orange, yellow, green, blue, indigo and violet, are in reality so many sensations, and all of them the subjective sequels of the same sort of vibrant energy, viz., solar radiation, each sensation representing a different rate of vibration. Why one of these sensations should be heat and another one green, we cannot possibly know. All we can say is that the mode of motion communicated to certain of our tissues we call heat, and that communicated to certain others, green. That it is a

mode of motion, we have no reason to doubt. We know that motion can no more be lost or cease to be, than that gold can be annihilated. It may be locked up temporarily, as potential energy, but it can never become anything else than energy, either on a strain or in motion. It is transferred from one body to another, each body in turn moving according to its peculiar constitution, and ceasing to move only when its motion is communicated to another. In this way we are able to trace the vibratory motion of the ether to the eye, where it ceases in that form, and is succeeded by a molecular vibration, called a nerve current, which passes to a cell in the sensorium, and is succeeded there by the motion called *green*, or *blue*, or whatever it happens to be.

Again, the lecturer observes: "The sense organ, the nerve, and the sensorium taken together constitute the sensiferous apparatus. They make up the thickness of the wall between the mind, as represented by the sensation, 'muskiness,' and the object as represented by the particle of musk in contact with the olfactory epithelium," in other words, between the sensation and the object from which it was reflected. Then he goes on: "It will be observed that the sensiferous wall and the external world are of the same nature; whatever it is that constitutes them both is expressible in terms of matter and motion. Whatever changes take place in the sensiferous apparatus are continuous with and similar to those which take place in the external world. But with the sensorium *matter and motion come to an end, while phenomena of another order, or immaterial states of consciousness, make their appearance.* How is the relation between the material and immaterial phenomena to be conceived?" Three hypotheses have been proposed.

"The first is that an immaterial substance of mind exists; and that it is affected by the mode of motion of the sensorium, in such a way as to give rise to the sensation. The second is that the sensation is a direct effect of the mode of motion of the sensorium, brought about without the intervention of any substance of mind. The third is that the sensation is neither directly, or indirectly, an effect of the mode of motion of the sensorium, but that it has an independent cause. Properly speaking, therefore, it is not an effect of the motion of the sensorium, but a concomitant of it."

The lecturer holds that neither of these can be proved, but prefers the second one as the simplest. Yet he says the third cannot be refuted, and of the first he observes, "An immaterial substance is perfectly conceivable. In fact it is obvious that if we possessed no sensations, but those of smell, and hearing, we should be unable to conceive a material substance. We might have a conception of time, but could have none of extension, or of resistance, or of motion, and without the three latter conceptions, no idea of matter could be formed. Our whole know-

edge would be limited to that of a shifting succession of immaterial phenomena. But if an immaterial substance may exist it may have any conceivable properties, and sensation may be one of them."

I agree that the sense organ, the nerve, and the sensorium, and the changes that take place in them, are to be described in terms of matter and motion of matter, and that these changes are continuous with and in principle similar to those which take place in the external world. It is doubtless true too, that "with the sensorium matter and motion come to an end" so far as psychical phenomena are concerned. But it is by no means to be admitted that this ending of the motion that constitutes the function of the sensorium, is succeeded by the appearance of "phenomena of another order or immaterial states of consciousness." When the motion of the sensorium has ceased, the "state of consciousness" has ceased. It is true that the state of consciousness is immaterial because that term, "*state* of consciousness," describes the motion of the sensorium, and that is immaterial indeed, though neither more nor less so than the motion of a falling stone, or of a ticking watch, or of a waving flag, or of a ringing bell, or a pulsating atmosphere, or of a beam of solar radiation. All *motion* is immaterial. The *motion* of matter is just exactly as immaterial as the motion of any conceivable or inconceivable immaterial substance. So we are not called upon to answer the question "How is the relation between the material and the immaterial phenomena to be conceived?" I take it, all phenomena are to be described in terms of motion and that therefore there are no material *phenomena*. If, however, by the expression "immaterial phenomena" be meant the phenomena of an immaterial substance or existence, then the question arises, has the existence of any such substance been proved, or if it is merely hypothetical, does such hypothesis in any way help the solution of the problem of consciousness.

Consider the first of the three hypotheses mentioned above; viz., that there is an immaterial substance which is set in motion by that motion of material substances which ends in the sensorium. That is to say, a motion of matter beginning in the environment continues to be a motion of matter in some form or other through the sense organ, the nerve, and the sensorial cell, then it ceases as the motion of matter, and is continued as the motion of a substance or existence, or entity which is not matter; and this motion, or the way in which this substance is affected, as Prof. Huxley has stated it, "gives rise to the sensation." Now if the "affection" or motion, and I cannot conceive of any sort of affection which is to be described in any other way than in terms of motion, if this motion of the immaterial substance is not itself sensation, but merely "gives rise" to it, then we are left to imagine another remove still, and something else beyond this first instalment of imma-

terial substance. But if we ever do get there we are bound to find sensation to be a motion of something, and unless we are willing to throw over the well ascertained law of the conservation of energy to accommodate an hypothesis, we shall have to admit it to be the continuation and dynamic equivalent of a motion of matter. And if this is the case we are under the further necessity of recognizing the phenomenon as still being within the domain of physics, regardless of the designation "immaterial" or any other name we may choose to give it.

It is true we talk of "states of conciousness," but we must not mislead ourselves by such language to imagine this is a permanent condition of rest, into which we can get ourselves, and in which we remain motionless for an indefinite time. When we are conscious we are conscious of some definite thing. Consciousness of a definite thing is a sensation, and vice versa. A sensation relating to anything endures only so long as force or energy is reflected from that thing, or its representative in our internal sense organs, upon the sensorial cells. The moment that motion stops, sensation stops. I think it is not necessary to repeat the proofs of this given elsewhere, but assuming it proved that sensation is motion, the inquiry narrows down to the question, how the motion can be transferred from the material substance of the sensorium, to the hypothetical immaterial substance, the motion of which is assumed to constitute sensation? Can we suppose that the impact of a material substance against an immaterial one can communicate motion to the latter? Can we conceive of such an impact at all? The only condition on which we may conceive it possible, is that the immaterial body being at rest, offers resistance to the impact of the material body, and receives motion from it equivalent in its kinetic energy, to that which has been lost by the material body. If there has been no resistance, there can be no loss of energy on the part of the material body and therefore no transfer of motion, and no sensation at all would be the result. If we find *resistance* as a property of this hypothetical immaterial substance we shall be compelled to denounce it as masquerading under a false title, for *resistance* is a property of matter. But if the difficulty in conceving how motion can be transferred from the material to the immaterial substance be supposed somehow to be obviated, we immediately encounter another and similar trouble in accounting for the whereabouts and disposition of the energy after it ceases to be sensation, for we know it soon does so cease.

On the theory that the molecular motion of the material belonging to the sensorial cells themselves, constitutes the sensation, this difficulty does not occur, for sensation being therefore a form of energy, it is convertible into heat, which is another form, but which is simply the molecular motion of matter. But we cannot allow this disposition of it, if we accept the immaterial theory. It cannot be dissipated as heat in the

immaterial body, since such body has no material molecules, nor can it be that it is transferred back again as heat from the immaterial to the material body, for that implies impact and resistance, which can occur only between material bodies.

Furthermore we have found that these sensations are links in a chain of causation, and that they are not merely stub tracks that run out into the wilderness of mystery and stop there, having in this process, in some unaccountable manner, in defiance of the laws of physics, made away with and totally annihilated a quantity of energy. On the contrary these sensations act like other forms of physical energy, and on disappearing (often) transfer the energy that constituted them to other movements in the construction of a will, leading on to motor impulses and muscle contraction. So that if it is supposed to be the motion of an immaterial substance that constitutes mind, we incur the impossible task of accounting for its physical impact upon the tissues that set up the efferent current.

It is probably true, as Prof. Huxley says, "that if we possessed no sensations but those of smell and hearing, we should be unable to conceive a material substance." But we would certainly be no better able to conceive an immaterial one, than we are now. Sounds and odors do not emanate from immaterial substances. All we can say is that those two senses alone cannot give sensations from which adequate ideas of anything can be formed. It is true, that with these two senses alone, "our whole knowledge would be limited to that of a shifting succession of immaterial phenomena." But that is what our knowledge is limited to anyhow, with all our senses in full blast. If by "immaterial phenomena" is to be understood the phenomena of immaterial things, then I maintain that if the senses of smell and hearing, taken alone, tend to give us an idea of immaterial things, they are simply deceiving us, because odor and sound do not emanate from immaterial things, are not reflected from such things, do not represent such things, and have no connection with them in any manner or form. But it is purely an assumption that these senses, acting alone, would produce such an idea, and I deny it. An animal, having only these senses, would have no abstract ideas at all, and very few concrete ones. If he got an idea that there was any *thing* from which the sound or smell emanated, it would be to him simply a *thing*, no question of materiality or immateriality could possibly arise. Furthermore, I deny that an immaterial substance is at all conceivable. All conceptions are made up, ultimately, from sensations, and every sensation is the result of the reflection of energy from material bodies. It is not necessary to repeat the arguments given elsewhere in proof of this. Every work of reason or imagination, every poem, every dream, every "sum" in mental arithmetic,

every problem in conic sections, is a production reflecting relations real or possible, between material objects, and possible to be put together only through the means of sensations, following sensory impressions. It is needless to say that no sensory impression ever followed the impact of energy, reflected from an immaterial substance; simply because, by its definition, any substance, which reflects energy, is a material substance. If no conception can contain any elements of energy, not reflected from material bodies, then all conceptions must be of material bodies, and a conception of an immaterial substance is, therefore, impossible.

The description of an immaterial thing is made up of negative definitions, denying to it every quality possessed by ponderable matter—as extension, weight, visibility, &c., and of positive definitions assigning to it qualities, which belong to the motions of matter, such as force, quantity, &c., and especially those motions of the nervous system, which we call love, hate, consciousness, &c. The definitions then really make it, not a thing, but a motion of a thing. A *thing* does not come and go, as consciousness does. When a particular brain cell is erethised, there is consciousness. When the excitement of the cell is over, the consciousness is gone, while the cell is still there. The thing remains, while its *motion*, a non-thing, has ceased to exist. But having assumed, absolutely without proof so far discoverable, the existence of an immaterial substance, what then is known about its properties? "If an immaterial substance may exist, it may have any conceivable properties, and sensation may be one of them." Since assumptions don't cost anything, you may as well assume a plenty while you're assuming. But if after compelling yourself to believe you are thinking of an unthinkable immaterial substance, you have still got to assume that it is endowed with sensation, I do not see what has been gained. This assumption could have been made in the first place, in regard to the sensorium—if nothing better than assumption presented itself.

The immaterial substance *may* have sensation for one of its properties, and then again it may not. I do not pretend to say that it is conceivable how a mode of motion of brain elements is a sensation. I only contend that the facts indicate quite positively that it is so, and being so it is just as conceivable as most other things we are obliged to accept, as gravitation, chemism, the construction of water, and of flame, growth, &c. And it is just as conceivable as the notion that movements of an immaterial substance could constitute mind. My principle objection to the immaterial conjecture is not so much that it is inconceivable, as that it is utterly baseless and unsupported by a single fact in any part of the universe accessible to us. Then why has it been considered necessary to make this violent and unnatural assumption which

does nothing whatever toward the explanation or elucidation of the subject, but simply gets rid of it by banishing it to the obscure regions of mystery and myth? The notion of an immaterial substance originated before there was any adequate idea of the nature of energy, and its relation to matter, before the discovery of molecular motion, and when all matter was thought of and spoken of as *dead*. It was not conceived possible that this dead matter could ever get itself into motion, but must have been started by some powerful, personal being. With such notions of matter it could not be conceived that sensation or consciousness could in any way be connected with it. But ideas of matter have undergone a radical change within the last two or three generations. When matter is mentioned now, our thought of it is no longer confined to iron by the ton, or gravel by the wagon load. We have become familiar with the chemists' conception of atoms and molecules, a molecule of water being according to the estimate of Sir W. Thompson, less than one, two hundred and fifty millionth ($\frac{1}{250\,000\,000}$) part of an inch in diameter[1], and with the physicists' conception of the activity of these molecules when under the influence of force applied from without. The conception too of the existence of an all pervading ether as the vehicle of the energy which creates in us the sensations of light and heat, is familiar to all. Then we are under the necessity of conceiving of the matter whose motion constitutes the phenomena of electricity and magnetism supposed by many to be the same all pervading ether.

We very soon exhaust our powers of imagination when we attempt the conception of these indisputably material entities and their motions. J. P. Cooke says of the molecules of a gas that they are as real as the planets. Thompson says they are "pieces of matter of measurable dimensions with shape, motion, and laws of action, intelligible subjects of scientific investigation." All the enormous energy of the sun's radiations has for untold ages been whisked away to every part of the universe, the portion falling upon our pigmy earth and her sister planets, being but an infinitessimal part of the whole. Yet inconceivably vast as it is, it has all passed from particle to particle of this ether, a substance which delivers the impact of its motion to our senses of sight and feeling at the speed of 186,000 miles per second, but which when at rest has never manifested itself to a single one of our senses; and it allows the earth to rush through it at the rate of more than 1,100 miles a minute, without causing a perceptible retardation to its motion. If we attempt to give ourselves a realizing sense of the facts and figures relating to this substance ether, we at once find our comprehension too narrow to reach around them. Thus according to the table on page 383, we find that the length of the wave of this substance which

[1] Thompson estimates the no. of molecules of any gas in a cubic inch at 100,000,000,000,000,000,000,000, or 10^{23}; 23d power of 10.

gives us the sensation we call red, is so short that it takes about 37,000 of them to make an inch. This we can conceive of because if fine steel were ruled as closely as that we could see the spaces by means of a powerful microscope. But in order to give us the sensation of red it must move, for when it is at rest it gives no sensation, that is, it is black. There are 11,784,960,000 inches in 186,000 miles. This number multiplied by the wave length of red, gives 435 trillions, (or 435 millions of millions) as the number of undulations caused to take place in this substance one after another, but all within one second of time, by the energy of the molecular motion of some incandescent body. It is easy to *say* 435 trillions, but we can not *conceive* of that number of units within that time, nor within a lifetime. Our sensation of an impact at this rapidity upon the retina is red, and conveys no idea of a number of units. Neither sensation nor conception, except of the most vague and inadequate sort, can be affected by such an agent, except in the mass. The ray of the extreme violet which is at the other limit of our color octave, is produced by 871 trillions of vibrations per second, or double those of the red ray. Here the susceptibilities of the materials of our sight organ fails. The rays above the violet produce no sensation in us, and conception of them totally fails. We know that such rays are there, and we learn through their action that delicate as the molecular balance of our retina seems to be, there are chemical adjustments in *unorganized* matter of a far more delicate nature, since they can be disturbed by these ultra violet rays which cannot affect our sense organ. (See page 398.) For anything we know, the reactions set up by the ultra violet rays in chemical compounds are of a more subtile and delicate nature than those we call sensation. Certain it is we do not need to climb outside of the domain of physics to find material substance of an inconceivably refined constitution; and phenomena strictly immaterial.

I now quote again from the lecture on automatism: "I am utterly incapable of conceiving the existence of matter if there is no mind in which to picture that existence." Since there is no contingency about the fact that we do have a conception of the existence of matter, I suppose the above declaration is equivalent to saying that this conception could only have an existence in connection with mind, and so is proof of mind. The idea seems to be that the conception is a picture, and the mind is the object or substance upon which it is drawn. As I have defined mind, conception *is* mind, but as considered in the quotation, conception becomes an *act* of the mind, for certainly the word "picture" is not intended to imply a permanent impression or imprint upon a mind substance like a photograph. If conception is understood to be an *act* of the mind, it is motion of the mind, and since the con-

ception is a conception of matter, this motion of the mind is due to an impact of matter upon mind, which set it going. It may seem a little more realistic to use concrete instead of abstract terms, so instead of "matter," let us say "ship." Now sunlight striking the ship is reflected to the retina, there converted into a nerve current which runs into the brain, finds the mind, and sets it going; and this going *is* the act of the mind, and *is* a conception of the ship. Now the main thing to be considered here, is that this "mind" is set in motion by the impact of physical energy, and it must therefore be a physical body, and further that its motion being the movement of a physical body must therefore be a form of physical energy. The conception of something else is another form and so on. If in the above quotation we substitute for "mind," the word "ether," or some other, expressive of the idea that the substance in question is subject to physical law, we get a sentiment that accords with known laws. There is nothing in a name, provided it is understood, but if "mind" is used to mean the substance that moves, and conception, thought, emotion, etc., are its acts, then some other word must be used to express the aggregate of these acts. Webster defines mind to be (chiefly), "intention, purpose, design, inclination, will, desire, opinion, memory, &c. This is the sense I have given it. Surely love, purpose, memory, &c., are not *things*; they are acts or movements, and together properly constitute the *mind*, while the substance that moves, the material ether of the cells is the *soul.* An *immaterial* mind or soul considered as a subtance, is an exceedingly thin substance on which to make a literal picture of a ship, or in which to set up any sort of motion by the impact of a material substance, or from which to look for impact competent to set up motion in a material body. Ether is thin enough, and it satisfies the condition of being competent to receive and deliver blows. If any one objects that he cannot conceive that the motion of ether could be an idea, he will have to show that it is more conceivable that the motion of an immaterial substance could be an idea. He must do more, for he must show that an immaterial substance is capable of being set in motion by physical energy, or any other sort of energy, if there be any other.

It may be considered a proof that an idea or conception is a mode of motion, and not a state, that it endures only during the continuance of the physical motion that sets it up. Thus, if we gaze at a red brick, a nerve current at once starts toward the brain and keeps running as long as we gaze, and as long as it runs we experience the sensation red. But the moment the eyes and attention are directed to another object, the current running to the "red" cells of the brain ceases, and the sensation of red instantly vanishes. And if it comes into consciousness again it does so from being restimulated by energy from another quarter, as the internal sense organs, producing a recollection.

Now it has been said that nerves and cells, and the current of nervous energy can be described "in terms of matter and motion," while (the sensation) *red* cannot. At first sight this may appear so, especially if we fail to reflect that we are by no means acquainted with all the "terms of motion." For a thousand generations men knew that if a blacksmith should pound a piece of cold iron it would get hot. They would have described the operation of pounding in "terms of motion," but they never suspected that the heat imparted to the iron could be described in terms of motion too. It did not look anything at all like what they had been accustomed to regard as motion of matter. And in truth it has no resemblance to the waving of a flag, or the falling of a stone, or the flight of an arrow; and the proof that it is energy, or the motion of matter is circumstantial. We see energy consumed in getting the iron hot and with proper contrivance we can get energy out of it as it parts with its heat. It is in just such a way that we get at the conclusion that there is the progressive molecular agitation of the nerve fiber which we call current, ending in a cell agitation which we call *red*. We see energy consumed, can trace its movement and perceive its manifestation as sensation red. I admit sensation red does not seem to us at all like many other sorts of motion. It has little resemblance for example to the stroke of a bell-clapper. But the vibration of the bell following the stroke of the clapper does not much resemble it either. This is followed by the vibration of the air which does not seem like *red*, nor like the stroke of the clapper. And lastly in this series is the sensation *sound*, which has no resemblance to stroke of clapper, or to sensation *red*. But we feel sure that sensations *sound* and *red* do belong to the same genus of phenomena. They are both motion of the same sort of substance whatever it is. So the stroke of the clapper and the current up the optic nerve are both motions of matter, but they strike us as being no more like each other than either is like *red* or *sound*. We do no violence to any fact we know in relation to them when we describe all four of these phenomena in the same terms of motion. Thus they are imponderable and absolutely destitute of density. Although inseparable from matter, they are not matter. There is one positive attribute they all possess in common, and that is quantity. (Matter also possesses an attribute we call quantity, but the two can scarcely be said to be alike). Each one supervenes and subsists upon the disappearance of an antecedent form of motion, and is one of an infinite series in time, and part of definite quantity, which as a whole is indestructible, and which cannot be increased or diminished. There is this difference between sound and movement of the bell-clapper, that the former is part of our own personality while the latter is not. We may get more than one sort of sensation from the movement

of the clapper because we can bring more than one sense to bear upon it so that we can get an *idea* of it; that is we can compare it with something else having points of resemblance or difference. But the sensation *sound* is the movement of some of our own tissues, and as shown above, since these are the ultimate terms in the series, so far as our ego is concerned, we can get no *idea* of sound. All we can do is to get its repetition (in memory), by the reagitation of the same tissues, and when this is done we have the same sensation in reduced volume that we had at first, and so all we can say about it from such test is that sound is sound. We might objectively examine such tissues in another brain, and while they were to their owner such sensation, they would be to us merely a vibratory quiver; just as a deaf man might inspect a ringing bell and *see* its motion and *feel* its vibrations without the least conception of sound.

Our ideas of what constitutes motion are largely matters of habit. We now regard heat as motion, with no more question than we do the waving of a flag. But it was not so with our ancestors. They thought of it as a substance, and called it caloric.

The third proposition mentioned by Prof. Huxley requires to be noticed; viz., that sensation originates independently of the motion of the sensorium, but it is a concomitant of it. Something like this seems to have been the opinion of *Prof. Bain.* He says the mind and body are inseparable, and he appears to believe that mind and body grow up together, being linked to each other from the very beginning, a unit which he calls mind-body. He says, without the physical alliance "we should not have mental states at all." Prof. Bain sees and states the facts, but he is barred from any intelligible explanation of them by the persistent fetish of an immaterial mind considered as a thing or substance. He saw the two together as he supposed, but realized the impossibility of accounting for the union of two things utterly destitute of common bonds, belonging, as they seemed to do, to entirely different kingdoms, and amenable to entirely different sorts of laws. He says, "We have every reason for believing that there is in company with all our mental processes *an unbroken material succession.* From the ingress of a sensation to the outgoing responses in action, the mental succession is not for an instant dissevered from a physical succession. A new prospect bursts upon the view, there is a mental result of sensation, emotion, thought, terminating in outward displays of speech or gesture. Parallel to this mental series is the physical series of facts, the successive agitation of the physical organs, called the eye, the retina, the optic nerve, optic centers, cerebral hemispheres, outgoing nerves, muscles, &c. While we go the round of the mental circle of sensation, emotion, and thought, there is an unbroken physical circle of

effects. It would be incompatible with everything we know of the cerebral action, to suppose that the physical chain ends abruptly in a physical void, occupied by an immaterial substance; which immaterial substance, after working alone, imparts its results to the other edge of the physical break, and determines the active response,—two shores of the material with an intervening ocean of the immaterial. There is in fact no rupture of nervous continuity. The only tenable supposition is that mental and physical proceed together as undivided twins."[1] This states the case extremely well, and but for the bias of a preconceived notion of an immaterial stuff, ought to have suggested the truth to its writer. As this incongruous notion had to be injected into every solution that was attempted, it instantly rendered the whole matter insoluble, and practically Bain leaves the question just where he found it. He says, "There is an *alliance with matter*, with the object or extended world, but the thing allied, *the mind proper*, has itself no extension, and cannot be joined in local union." "The only mode of union that is not contradictory is the union of close succession in *time*." "We are entitled to say that the same being is by alternate fits, object and subject under extended and under unextended consciousness; and that without the extended consciousness the unextended would not arise." That is, without the cerebral and nervous organization which is the "extended and material mass," we would not have "the power of becoming alive to feeling and thought, the extreme remove from all that is material." This last sentence expresses the truth, although its true import was completely missed by its author. There is certainly an inseparable connection between the material nervous, and cerebral elements and their functions of feeling and thought. But when we come to understand that feeling and thought are simply motions or agitations of the subtile and refined materials which compose these elements, not only does the difficulty of comprehending how material elements can be joined to immaterial phenomena vanish, but we see that there is no possibility at all of the latter being separated from the former. According to the dynamic theory, all motion is the motion of physical bodies. The character of any particular mode of motion depends upon the peculiar constitution or form of the matter to which motion is imparted. Long as the earth has existed, there was never on it the motion we call walking, till an animal came into existence possessed of legs. There never was the peculiar motion we call ringing, until a metallic instrument was constructed of such elasticity and peculiar form that it rapidly recovered its shape after being distorted by a violent blow. There never was the motion we call sound, until an organization of peculiar nervous elements and construction had come into existence. As sound *is* sensa-

[1] Bain, Mind and Body.

tion, it follows that the rise of sensation depends, like other modes of motion, on the constitution and form of the matter concerned in its production.

Each sensation being motion, and a continuation of antecedent motion, it necessarily ceases the moment the antecedent motion stops. When the sensation is revived as memory, it is still in consequence of an antecedent motion or stimulation coming from another part of the brain or nervous ganglia, and it stops at the instant such stimulation stops. The mind being made up of sensations, and the secondary products of sensations (as shown in previous chapters), it disappears whenever the stimulations adapted to produce the sensations cease. When a man is asleep, his mind has nearly all disappeared. The machinery is there in the shape of the brain and nervous system, for the reproduction of the mind just as soon as the energy is applied again to the machine. The mind may be compared to an electric light, the brain to the dynamo by which it is produced. When force is applied to drive the dynamo, the light flashes into existence. When the dynamo is still, there is no light. So when the brain is still, there is no mind. To make the comparison more exact however, the brain is a multitude of dynamos, each one when running producing a different colored light, that is, a different sort of sensation. They are never all running at once, rarely more than one or two at the same moment, so that in reality only a small amount of mind is in existence or on exhibition at one time. Of the rest we can only say that the potentiality of it exists in brain cells fitted for its production when the proper force is applied, but, until it is applied, it no more exists than does the electric light while the dynamo is at rest. In fact the principle which underlies mental action is precisely that which governs the motions called light and electricity, and the immediate agent whose motions constitute them all is the same universal ether, its different manifestations depending upon the different forms of ponderable bodies with which it is associated; viz., carbon points for the light, the iron dynamo for the current electricity, and the brain for the mind.

The comparative natural history of mind no doubt corresponds with the comparative anatomy of the brain and nervous system. Of the three departments of mind, we trace reflex action to the lowest of the animals, and some plants. The lower departments of thought, such as perception, are found in all animals possessed of external sense organs; eyes, auditory and olfactory organs. Sensibility, too, must be attributed to animals very low in the scale of being. The sort of sensibility that is common to almost all animals arises from the conditions of the vegetative system, especially the stomach. Animals may have sensibility from this cause before they possess acute sensations relating to the en-

vironment outside of the body, that is, the objective sensations. It might be rash to assume that the simplest animal that eats does so from the stimulation of an unpleasant sense of "goneness." But we know we do so ourselves, and when we observe the other mammals eat, they exhibit every indication of being actuated by the same motive. They appear to endure the pains of hunger, and enjoy the comfortable sense of satiety. As we descend the animal scale, we find the fishes eagerly pursuing their prey, or cunningly lying in wait for it, undoubtedly animated by a similar impulse, thus exhibiting not only sensibility, but foresight, imagination, and reason. The higher genera among the mollusks, such as the octopus, express themselves in their actions as the fishes do. If we go lower the actions become less demonstrative, but with the lowest, the stomach, or body cavity, is a hungry receptacle for whatever food comes in its way, and a center from which come impulses to set in motion whatever machinery of limbs the animal possesses, for the apparent purpose of keeping this receptacle supplied. The physiological basis of the sensation of hunger is without doubt the unsaturated chemism of the elements that compose the tissues of the wearing parts of the body. This physiological basis exists in every animal from the amœba up to man. In the former, and in other simple animals, this unsatisfied chemism is perhaps all the force there is for the acquirement of food. An amœba, a sponge, or a rhizopod to which a supply of food is simply a lucky accident, and which therefore does not make an effort, absorbs its food probably without sensibility or previous sensation of hunger. But somewhere in the scale of life, and not very far above the lowest, the *sense* of hunger does accompany the unsatisfied chemical state of the tissues. It is superadded to it and appears somehow *to grow out of it*, or at any rate it is developed in relation to it, and in all animals that are active in pursuit of food it becomes the chief incentive to exertion. The pleasurable and painful sensations which arise in connection with the animal or outer part of the body, such as those due to temperature, pressure, contusion, &c., are of later development; while those relating to companionship, care for the young, and the emotions, anger, attachment, rage, fear, &c., are still later. There is a gradual development of sensibility in relation to more and more of the animal activities as we ascend the scale, the sensibility without doubt following close upon the development of the activity.

We may divide subjective sensations into two general classes, which may be styled the positive and the negative; for it is apparent upon reflection that the state of the tissues in which the chemism is unsaturated, has its antithesis in a condition in which it is satisfied and in which any further stimulation produces repulsion instead of attraction, that is, nausea or disgust instead of hunger. While hunger is probably the

first developed of the positive sensations, it may also be regarded as a type of all the rest. Unsatisfied chemism, which as observed above is the essential antecedent of hunger, is a condition in which the poles or bonds of the molecules remain unengaged and ununited. (See fig. 403.) I conjecture that it is the energy of the polar forces of these unengaged bonds that expends itself in setting up the positive sensation; the sensation being the reflection into the nervous ganglia of this unsatisfied attraction, an attraction without an object at hand to be attracted. The principle is the same for the other forms of positive sensation, the difference being in details. There are numerous subdivisions of hunger. We may be hungry for something sweet or something sour, substantial or delicate, dry or wet, or some special thing, as potatoes or beef, or kraut or beer. These different sorts of hunger depend upon the fact that different sets of tissues are involved, some being deficient in and demanding one element, and some another, the energy of the deficiency or demand transferred to a nervous ganglion becoming the sensation of that particular want.

All sorts of *desires* naturally range themselves alongside of hunger, as belonging to the class of positive sensations. Earliest among these are the desires for sexual companionship, for shelter, for clothes, and then for wealth generally. Following these come desires for power, fame, distinction, intellectual and esthetic gratifications. Mixed with these desires and scarcely separable from them are such sensations as love, sympathy, affection, pity, piety, hope, aspiration, joy, anticipation, gladness, which are more or less compound. Sometimes the terms are used without discrimination. Thus if a man has no wealth he may desire it. If he has enough he may love what he has, and not desire any more. A swain desires his sweetheart but loves his wife. A mother loves her children, after they are born; before that she desires them. It often happens that the two sensations are expressed by one word and not properly distinguished. But love is akin to the sense of satiety or satisfaction that follows the removal of the conditions of hunger. If one continues to eat after he is satisfied, the result becomes disgust. Love follows desire, as the object of desire comes within reach, thus becoming in part incorporated with our personality; the desire, a hunger, being gradually appeased as the unengaged bonds of the tissues involved are one by one saturated. A so-called love known to be hopeless by the one who entertains it, is not love at all in the proper sense of the term, but infatuated desire. Love then appears, as desire is satisfied, and does not reach its full estate till desire is entirely eliminated.

The man who spends his life in scrambling for wealth, after he already possesses a fortune, can hardly be said to love wealth so much as

desire it, since his appetite is never satisfied. He is like a man with a tape worm, who gets no satisfaction from what he eats, but constantly desires more. If the money maker were forcibly restrained from seeking more, after he has enough, his attention would be turned to the assimilation, and the enjoyment and love of what he has. An excess of the conditions that produce pleasure or satiety, brings a pall. Too much of that which creates love causes a "sickish sweet," and finally a disgust. Love, joy, and gladness, indicate states of satisfaction, bounded on one side by desire, and on the other by disgust.

As hunger is the type of the positive sensations, so nausea is the type of the negative ones. The physical basis of these is repulsion instead of attraction. In electricity two bodies that at first attract each other in a short time come to be charged alike and then they repel. If they are charged alike in the first place they repel from the first. This illustrates if it does not state the identical case of the basis of the negative sensations, these sensations being the reflections of conditions of repelling or antagonistical movements in certain tissues. The sensations that come under this designation are such as disgust, dislike, aversion, hatred, anger, rage, melancholy, sorrow, dread, alarm, fear, fright, terror, panic, &c. Those sensations that represent satisfaction and balance in the polar condition of the tissues are pleasurable, and on one side of these are the sensations that represent unsatisfied attractive bonds, and on the other those representing repelling elements. Both of these are in a greater or less degree uneasy and painful. (See chap. 67). The final tissues involved in these sensations in man and the higher mammals appear to be those of the brain, or at least those are the ones which together form the seat of the general consciousness; and although the conditions of the tissues of the body generally, such as the muscles, the stomach, the sexual glands, the liver, heart, kidneys, &c., constitute the bases of very many of the sensations both pleasurable and painful, there are many others which arise only from conditions in the internal sense organs of the brain and the manner in which they are affected by new incoming stimulations from the environment, as pointed out on page 712. The organs of thought are a part of the environment to the organs of sensation, so that their states, as before observed, furnish a large share of the stimulations by which organs of sensation are set up in the first place, and revived in recollection afterwards.

CHAPTER LXXXV.

THEOLOGICAL CONSIDERATIONS.

If the conclusions reached in the foregoing chapters are correct, I think it must be admitted that they subvert the theory of the immortal-

ity of the soul. If the mind is simply an aggregate of phenomena, the sum of the motions of something, of course it ceases or dies whenever the substance of which it is the motion ceases to act. And this must be true whether we consider the soul material or immaterial. The motions constituting mind cannot be supposed to exist after the dissolution of the thing that moves, any more than the waving of a flag, or the ticking of a watch continues *as such* after the flag and watch have been destroyed. The effects of all of our acts go on in other forms of motion, because being a part of the sum of all physical energy, they cannot be lost. But for the very reason that our acts do thus pass into other forms of motion, they cease to be our acts. If the movements that *have been* made by our hands no longer exist as such, neither is it possible that the movements that *have* constituted our minds from day to day any longer exist. And as any future movement of the hands depends upon the continued integrity of the hands themselves, so any future manifestation of mind depends upon the continued integrity of the organism whose motion it is. As we have seen that mental phenomena, during life, depend constantly and absolutely upon the integrity of the brain tissues, and that when a portion of the brain is destroyed or diseased a certain definite sort of mental action thereupon ceases to be performed, the conclusion appears obvious and inevitable, that when the brain is all gone, there is an end to all possibility of any further mental action. When the body and brain are dissolved, it certainly looks as if the machinery for the production of mind were totally destroyed. A disinterested observer could hardly reach any other conclusion. But we are none of us disinterested; and when a conclusion is greatly against our wishes, and our *habit of thought*, we naturally struggle against it. And so while appearances are decidedly against the theory of immortality, the sanguine believer in that doctrine will find reasons for disregarding them. For example, the ether which is concerned in mental operations, and which is supposed to conform, in the shapes it takes, to the cells and tissues with which it is involved, and the motion of which constitutes chiefly, or exclusively, all consciousness and thought, might be supposed to grow into a greater or less degree of consistency, density, and persistency, during life, so as to maintain its thus acquired constitution, through and subsequent to the catastrophe of corporeal dissolution. It might be supposed that this psychic post mortem person would still be in active communication with other such persons, and with others still in the body, by means of the *telepathic sense*, which would supply the loss of the ordinary corporeal senses. (See chap. 79). This sense might be supposed to become vastly more effectual, from the fact that the distances between the communicating persons could be reduced to zero, and thus the power, both

of absorbing sensations, and conveying impressions, be greatly enhanced. It is true that this post mortem person would be deprived of the *force* which, while he was in connection with the body, was supplied to him by the consumption of brain tissue, made good as fast as exhausted, by fresh accessions of new blood, which in turn, was periodically replenished by substantial meals of bread and beef; and so the sanguine speculator would be under the necessity of discovering some other source of energy to keep him in activity. Such a theory as this might prove interesting, or even fascinating, but the physical difficulties in its way must be considered insurmountable. The same difficulties, or even greater ones, follow the theory of the immortality of the soul, when the soul is conceived of as an immaterial substance. There is no possibility of considering any sort of phenomena in connection with an immaterial soul, or making it an object of scientific investigation. So that any notion of it we get is purely fanciful, and any account of its mode of existence or means of support, entirely out of the question.

There is much vagueness and confusion in the use of the terms *soul* and *mind*. I have all along used the latter word to signify the aggregate of the active phenomena, the sensations, thoughts, and reflections. I shall use the term *soul* to mean the part of the body concerned in the production of these phenomena, and whose motions *are* such phenomena. The soul then, is a thing or entity, while the mind is its motion, and is not a thing. The soul considered as a material thing, must be seen to be subject to the accidents of matter, liable to waste and requiring repair, or at least when functioned to be in alliance with other matter, the brain cells, that are thus liable. As an immaterial thing there is no way of considering it at all, either in connection with the body or out of it. Nevertheless a vast number of people have, or think they have, an idea of the existence of the soul apart from the body, some calling it material, and others immaterial. The doctrine of immortality has become the fashion, and to reject it is now commonly regarded heresy. Formerly the doctrine of immortality was associated with that of the resurrection of the body, but was of subordinate importance, because the soul of the dead, though in some sense alive, was supposed to remain in a state of inactivity or sleep, until the resurrection, when it would be revived and rejoined to its body. Now the notion of an active immortality has come to the front, and the doctrine of the resurrection of the body is ignored or denied.

It would be difficult to show that the theory of the independent existence of the soul has any vested rights as a doctrine of the bible. It is in fact a heathen idea. It was held by some ancient Greek philosophers and poets, and from them was adopted by the modern deistical speculators, and is now held by the heathen in many parts of the

world, and by the modern spiritualists. Of late years it has crept into the church, and the whole body of Christians have become inoculated with it, and they seem to have become half ashamed of the doctrine of the resurrection of the *body*, as grotesque, crude, uncanny, and absurd, and of lacking in esthetic, attractive, and desirable qualities.

Many of us can remember when sermons on the resurrection of the dead, pictured the dead bodies coming out of the earth and the sea, where they were buried, and the fragments of dismembered bodies flying through the air to meet each other; the soldier's leg from one distant battle field where he left it, and his arm from another, &c. The bible does not teach the resurrection of the soul, but of the body. St. Paul calls it a spiritual body, but still a body. "We that remain shall be *changed*, and the *dead* shall be raised," said he. Enoch, Elijah, and Jesus are said to have ascended to heaven, whole, not leaving their bodies behind. The creed says, "I belive in the resurrection of the body." Not the continued life of the soul, and permanent death of the body.

That the resurrection cannot be proved scientifically is nothing against it from the bible standpoint. Revelation is addressed to faith, not reason. There is no faith, and no religious merit in believing a thing that can be proved by sufficient secular testimony, or scientific demonstration; any infidel can believe that way. Tertullian showed the true spirit of faith in the declaration, "Credo quia impossibile est." He also had the true conception of the soul, denying the doctrine of its immateriality and incorporeality. See Lecky, Rationalism, 1-342.

The discoveries of modern science have, without doubt, had a great effect in modifying the views of Christians, especially Protestants. There has been a disposition to make the doctrines of the church conform to science, and the creeds, or at least private views, have been constrained to assimilate science and revelation into a harmonious system, in oblivion of the obvious fact that there can be neither harmony nor inharmony between two things which cannot possibly be brought into comparison or relationship with each other. The real inquiry for Christians to make is, what *are* the doctrines that have been revealed. Having ascertained these, an attempt to prove them true and scientific is equivalent to a denial of them as revelations. A revelation that can be proved is no revelation at all, but a science. *If* the doctrine of the resurrection is a revelation from the Almighty, then the dead will be raised with their bodies, which of course includes their brains and nervous systems with all the powers and faculties thereby implied, and thus the aspiration for life beyond the grave be realized. If Christians will stick to this faith without attempting to turn it into knowledge, the scientific probability that there is no organization of soul, separate from

that of the rest of the body, need not disturb them. But the habit of considering the doctrine of the immortality and continued activity of the soul, as a dogma of revelation, and then finding it called in question by natural facts, has had a tendency to produce a wavering of faith; and so Christians have undertaken, by searching amongst the sciences, to find facts to brace them up. They want to substitute knowledge for faith, which is precisely the thing they cannot, as Christians, do. The promises, and Christian doctrines, they treat as if they were old scientific discoveries that must be collated with all the new scientific discoveries, and they seem to be in constant dread that they will fail to correspond with, and be confirmed by them. The only hope for Christianity as a system of theology, is in its miraculous origin, and in the miraculous and supernatural character of its terms, articles and tenets. If they are not miraculous or supernatural, they are human. If they can be bolstered up, or weakened by scientific discovery, they are human, and weakly human at that.

The apostles' creed embodies in brief the articles of the Christian faith; here it is:

"I believe in God, the Father Almighty, Maker of heaven and earth, And in Jesus Christ, his only Son, our Lord; Who was conceived by the Holy Ghost, Born of the Virgin Mary; Suffered under Pontius Pilate; Was crucified, dead, and buried; He descended into hell; The third day he rose from the dead; He ascended into heaven, And sitteth on the right hand of God, the Father Almighty; From thence he shall come to judge the quick and the dead. I believe in the Holy Ghost, The Holy Catholic Church, The Communion of Saints, The Forgiveness of Sins, the Resurrection of the Body, And the Life Everlasting. Amen."

At one time it was possible to find human testimony for or against the clauses in this creed, relating to the birth, crucifixion, and resurrection of Christ. But no other part of this creed did ever condescend to place itself upon the plane of human knowledge. If it did, by what warrant could it claim a superhuman origin? It would not be entitled to such claim if its allegations could be verified, or its revelations discovered by the wit of man. Especially are the clauses that concern this argument, viz., "The Resurrection of the Body, and the Life Everlasting," outside of the limits of scientific inquiry. Every body knows, and always has known, that in the course of nature dead bodies do not rise again, and thereafter continue to live. It is simply the assertion of a supernatural miracle, and its acceptance is an act of faith, and never can be anything else. Science has nothing to do with the supernatural. Her province is the discovery of law, and miracles are all contrary to law. To the extent that any part of Christianity can be scientifically verified, it ceases to be religion, and becomes science.

At the close of the middle ages Christianity became corrupted with heathen philosophy, and became a heathen Christianity. The science of the 19th century bids fair to demolish this philosophy, and now the tendency seems to be toward the adoption of a scientific Christianity. But it is

safe to predict that within a century the church will have done with science, and every other modern and foreign accessory, will resign the pride of worldly knowledge, and be content with her ancient supernatural faith and humble morality. Such a position is unassailable. All human knowledge, all scientific discovery is subject to, and even invites investigation and criticism, and confirmation, correction, or rejection. A religion that submits itself to these conditions, descends from the supernatural to the natural, ceases to be a divine theology, and becomes a human science. And no theology as a human science can stand a day.

The language of St. Paul in relation to the resurrection of the dead, in 1 Cor. 15:44, is not correctly translated in our version. He says, It (the body) is sown a "psychic body," (soma *psuchikon, not phusikon,* as it would have been if he had meant to *say* physical or natural body), and it is raised a pneumatic body (*soma pneumatikon*). The English version in our bible conveys the idea that the physical body is *sown*, but another sort of body, not physical, is *raised*. But the *fact* is, *soma* means the physical body, and the text declares this body to be accompanied in life with a *psuche* or *soul*; it is a soma *psuchikon*, pyschic body, and as such it is buried or sown. In the grave the *psuche* is lost or transformed into the *pneuma* or spirit, and when the time for the resurrection comes, the soma is to be brought to life, and accompanied by this *pneuma*, it is to be raised a pneumatic body or "spiritual body." It is the same body, *soma*, that is "sown" and raised, and this can mean nothing more nor less than the physical or obviously natural body. A correct translation of the idea would be as follows "It is sown a physical body with a soul; it is raised a physical body with a spirit." As if some objector might say that the soul and spirit are the same, St. Paul immediately adds, "There *is* (such a thing as) a psychic body (soma psuchikon) and there *is* a pneumatic body (soma pneumatikon). For thus it is written he created the first man Adam, a living soul (psuchen zosan), the last Adam a revivified spirit (pneuma zoopoioun)."

The doctrine of the resurrection of the material body was generally believed by the mass of Christians till within the last half century. This doctrine was agreed to by the Unitarian materialist, Joseph Priestly, in England. In the year 1777, he published "Disquisitions relating to Matter and Spirit," in which, on page 49, he says: "Man, according to this system (of materialism), is no more than we now see of him. His being commences at the time of his conception, or perhaps at an earlier period. The corporeal and mental faculties, in being in the same substance, grow, ripen, and decay together; and whenever the system is dissolved, it continues in a state of dissolution till it shall please the Almighty Being who called it into existence, to restore it to life again."[1] Priestly claimed that this doctrine was in accordance with the teachings of the bible, which everywhere show "death to be a state of rest and insensibility." The heresy of Priestly for which he suffered the obloquy of the orthodox, consisted chiefly in his denial of the existence of the soul as a separate person or entity. Why this should be considered important by a church whose creed regarded the soul as essentially functionless and inert without its body, it is difficult to see. In 1843, Dr. Courtenay, English Bishop of Jamaica, published a book "On the Future States" in which he says, "The death of the body will cause a

[1] Quoted by Huxley's Essay on Priestly.

cessation of all the activity of the mind by way of natural consequence, to continue forever, unless the Creator should interfere;" and he maintained that in the grave "man lies spell-bound soul and body, under the dominion of sin and death," and that there is to be no activity, nor sensation of happiness or misery till after the resurrection of the dead.[1]

Sometime in the fifth decade of this century, George Bush, Professor of Hebrew in the New York University, published a book to prove the continued existence of the soul after death, and to disprove the doctrine of the resurrection of the body. He believed that at death a spiritual body is developed or disengaged from the physical body, and lives on forever, while the physical body decays and is resolved into its elements never to be revived or recover its identity. This was regarded as rank heresy by the orthodox; and an answer was written by Calvin Kingsley of the Methodist "Alleghany College," and published for the Methodist Episcopal church in 1847. In this answer which may be regarded as an authoritative announcement of the creed of the M. E. church on this subject, Mr. Kingsley tries to prove that the identical body which dies, will at the time of the general resurrection be raised from the dead, and that this resurrection will be miraculous, and entirely out of the common order of nature, and depends for its reality on the fact of the meritorious death and corporal resurrection of Christ. During the last 40 years there is no doubt that opinions similar to those of Prof. Bush have steadily gained ground, and are largely held by church members and others who vainly imagine they believe the bible. The spread of these opinions has been no doubt largely stimulated by the Spiritualists who claim to be possessed of experimental knowledge on the subject of the future state. The assurance with which this claim has been put forward, as based upon scientific facts, has proved too seductive to many Christians whom the realistic fashion of modern thought has made ashamed to carry about with them a blind faith, unsupported by provable facts. They have in many cases without really knowing it, abandoned their faith and taken up what purports to be a natural science instead, and they look for immortality, not because it has been supernaturally promised, but because they suppose it to be a natural and necessary condition of human existence.

But the abandonment of a dogma founded on a revelation, for another, or even for the same one, founded upon human knowledge or speculation, is not only a discrediting of the revelation, but of the power or Person, by whom the revelation was supposed to be given. All revelations must necessarily be attributed to a personal being or beings. The doctrine of the resurrection having therefore been considered a revelation from a personal God, the subversion of the doctrine

[1] Huxley on Priestly.

considered as a miracle, and the substitution for it of a aogma founded on observations of nature, must logically and necessarily lead to the overthrow of the idea of God being a person, and finally to the abandonment of worship and adoration. But in some of the Liberal churches, Peoples churches, &c., the old habit of worship not easy to be got rid of at once, has curiously and absurdly become transferred to a vaguely imagined power, essence, or creative energy which is somehow supposed to be at the head of affairs. But if any abandon the personal God of revelation they will not, by searching, find God in any place accessible to human wit.

Men's conception can by no possible means get above the natural; as shown elsewhere a conception of a supernatural is not possible. Not only so, but we must always fall far short of a full comprehension of nature. Natural phenomena may be divided into two classes; things we know, and things we do not know. We do not worship anything we understand. The phenomena not understood are those which have always been attributed to supernatural agency. Plagues, famines, storms, earthquakes, eclipses, lightning, and other such unmanageable or inscrutable phenomena have at one time or another belonged to this catalogue. It has been considered impious to clean up for the purpose of warding off a pestilence; or to put up a lightning rod for the purpose of steering the thunderbolt; or to take medicine to cure sickness; under the belief that pestilence, lightning, and sickness were the personal weapons of a supernatural power, an attempt to thwart which was deadly sacrilege. Our knowledge is like a clearing in the midst of a dense and interminable forest. Originally very small, every generation has industriously and painfully widened it until a man at this close of the 19th century finds himself unable to see across it. Within these wide and constantly widening limits, no phenomenon has been discovered which can be referred to a supernatural source. Every discovery has shown the connection between phenomena and natural causes; and reasoning from analogy, which is our only resource, we are bound to conclude that there is no warrant for supposing that in the parts of nature yet unexplored we shall ever find a clew that leads to the supernatural. The causes which remain as yet undiscovered we may reasonably conclude are of a piece with those which have been found out. The civilized and enlightened Liberal Christian of this closing decade of the 19th century, who has found out that light, heat, and electricity are not caused by a worshipful personality, but who yet bows down before the phenomena of consciousness and mentality, and invokes superhuman agency in the regulation and rectification of the human "heart," and the illumination of the human "mind," is like the Idolater ridiculed by the Prophet Isaiah in his chapter 44, verse 15, who burnt part

of a tree to warm himself, and made the rest into a God, and worshiped it. This modern man has taken Jove's thunder-bolt from his hand, and harnessed to his street car; and all the forces of nature which he understands he presses into his service, but of "the residue thereof he maketh a God, even his graven image; he falleth down unto it, and worshippeth it, and prayeth unto it, and saith, Deliver me for thou art my God."

There is no scientifically discovered God, and there never can be. A God can never be known to mankind unless he chooses to make a direct and special revelation of himself. A being making a revelation to men is necessarily a personal being; and the catechism is neither logical nor inspired in describing him as being "without body, parts or passions."

The conclusions that it appears we must arrive at, must be such as can be neither supported nor disproved by scientific research.

(1) If we are to have a future state of existence, it is because it has been so determined by a Personal Being superior to and outside of natural causes and effects.

(2) The continuation of our identity is to be accomplished, if at all, by the continuation or reconstruction of our bodies, that is by a resurrection.

(3) If we are to know anything about this provision for our future, it can only be through a special, direct, and miraculous revelation.

Whether there has ever been, or is likely to be such a revelation, it would be out of place to discuss in this book which treats only of natural agencies and operations.

CHAPTER LXXXVI.

ENERGY AND ETHER.

Origin of Energy. There is a distinction between energy and force. Energy is simply the motion of material bodies, large or small. Force is the measure of energy, its degree or quantity. We say the motion or energy is of great force or little force. Energy as we see it displayed about us shows us no final or ultimate origin. Behind each form of motion we simply find another form. We might suppose, if we burn a ton of coal under a boiler which puts heat into the water, which drives the molecules apart in the form of steam, that the energy of the steam originated in the coal. In one sense it does. But the coal only gives out energy which was packed away in it ages ago by the expenditure of the energy of sunlight and heat. Coal is made of trees and plants. And trees can only be built up by the energy of sunlight.

The green side of leaves is covered with the small cells called Chlo-

rophyl, which are the mouths by which the tree eats. Its proper food is pure carbon. Its only supply is in the atmosphere where the carbon is mixed with oxygen in the shape of carbonic acid gas. The plant of itself cannot separate the carbon from the oxygen, but the agitation of the sunlight upon the gas loosens the hold of the carbon and oxygen upon each other, and then the carbon molecules are absorbed by the leaf and carried into the sap of the plant. Trees, grass, and weeds formed in this way ages ago, and washed into lakes, or growing up and falling down in marshes, thus became formed into beds, and being buried under vast deposits of rock and earth, have finally become coal. The heat made by burning this coal under a boiler is energy that the sun projected upon this earth 80,000,000 of years ago, and has been locked up in that coal all that time. The heat and light which are now given off are simply a continuation of the energy of these ancient solar radiations waked from its long nap and resuming its activity. The force exerted by the man who shovels this coal into the furnace is likewise a continuation of the energy of sunlight. The muscles and brains of the man have been built up from materials taken from the bread and beef he has eaten, and these have been formed from the wheat and grass, which have grown by help of the sun's rays in the same way as the coal plants did 80,000,000 years ago. Thus all muscular and mental energy of man and beast is only a continuation of solar radiation in new forms. Then there is wind power and water power, and these too are products of the sun's rays. (See page 322.) We also have electricity produced by the action of the sun (page 338), and when it is produced artificially, it is still derived from the sun through coal or wood fuel, or by means of water power. Thus all the motion on earth, except that resulting from the attraction of gravitation, is only the motion of the sun's radiation, arrested and deflected into new forms and modes. *All except gravitation.* The sun gives a boy the power to throw a ball up into the air, but it comes down again by the force of gravity which appears to be an affection of every particle of matter in the universe, and is independent of the sun. The sun has it in common with all other bodies, and it is this power by which all the suns are able to hold their tributary planets to their allegiance and to establish the compromise orbits in which they travel. The force of gravity depends on the distance apart of the attracting bodies, decreasing according to Newton's law, in proportion to the square of the distance.

Thus a wagon load of sand weighing 2,916 pounds at the earth's surface will weigh only 729 pounds at a distance of 4,000 miles, and at 216,000 miles, it would weigh just a pound. At 240,000 miles, which is the distance of the moon, it would be attracted by the earth with the force of 0.81 of a pound. At 93,000,000 of miles (the distance of

the sun), the earth's attraction for it would be only $\frac{1}{26}$ of a grain, and if it were on the opposite side of the earth's orbit, its weight from the earth's attraction alone, would be reduced to $\frac{1}{104}$ of a grain. At the distance of the nearest fixed star, it would be immeasurably small. But if allowed to fall to the earth from such a distance, the force of its blow would turn it into gas as well as a part of the earth receiving the blow.

Thus the force of attraction diminishes with the increase of distance, and at an infinite distance, if that were possible, it would be nothing at all. But bodies falling under the force of gravity acquire greater velocity with the distance they fall, and when they strike the earth, the energy of the blow is increased in proportion to the square of the velocity so that if a body goes at double speed, its energy is increased fourfold; at triple speed, ninefold, &c. So it is easy to understand that an enormous energy is created or rather made *kinetic*, when bodies meet as the result of attraction from long distances.

Now if we were to suppose all the suns and planets in the universe to become stagnated, motionless and cold in the positions they occupy at this moment, and all matter to be suddenly deprived of the property of the attraction of gravitation, and every other form of attraction, we might, with some propriety, apply to matter the term *dead*. But now suppose it to be instantly re-endowed with that one property or affection of the attraction of gravitation; and at once all would be motion. The creation of attraction would be the creation of force, and the positions which the different bodies occupied with reference to one another would be potential positions. As pointed out (page 326), all potential energy tends to run down to zero, and convert itself into kinetic energy, so that worlds would fly toward each other with a constantly increasing velocity and force. The larger ones would become centers toward which smaller ones would tend with inconceivable force, and the shock of the collisions which would result, would convert the motion thus arrested into heat, great enough to turn the material of the solid bodies into gas, expanded into many millions of times its original bulk. Such an aggregation of gaseous matter is what astronomers call a nebula, of which there are many examples in the heavens. A nebula contains all the possibilities of a solar system. The energy developed by such a tremendous collision is enough to last while planets are formed, and while on them organic beings are slowly evolved through the tireless ages. The energy we live on, of which our sun has yet a great store, may have been born from such a collision. All its various forms could have arisen from that one catastrophe. We have seen how every form of motion may arise from other forms and be converted into other forms. Heat, light, magnetism, electricity, nervous energy, chemism,

and a thousand various modes of work have all been derived from the same source, the force of gravity converted into energy. The conditions for the production of energy, then, seem to be *ponderable matter*, that is, matter endowed with attraction, in masses great or small, placed at distances from each other. The greater the masses, and the greater the distances, the greater will be the energy which they develop; the development of the energy depending on the diminution of the distance by the motion of the bodies toward each other; and when they come together the greatest energy possible to that combination is developed. When the distances apart are the greatest, the *potential* energy is the greatest, and the *force* of attraction the least. When the bodies have rushed together, and distance is annihilated, the *kinetic* energy is the greatest, and the force of attraction the greatest. Thus *potential* and *kinetic* energy are reciprocal, one being exchanged for the other, and so are *distance* and *force*.

When masses big enough to form a solar system have rushed together from distances great enough to generate energy of heat sufficient to thoroughly disintegrate them and disperse their atoms in the form of an incandescent gas, the foundation for a solar system may be said to have been laid. Supposing the first effect of the collision and the subsequent dispersion to have been to set the entire mass spinning around a common center, as such collisions seen in whirlpools, whirlwinds, cyclones, &c., always do, the next effect would be a shaping of the mass into a spheroid which would soon become flattened at the poles or points of little motion, and greatly elongated through the equator or parts having the greatest centrifugal motion. The radiation of heat into space would allow attraction to draw the particles closer together, and thus reduce the bulk of the mass, which would be accompanied by an increase in the rapidity of rotation. The external part by thus acquiring a different motion from the central part, would tend to become independent of it. Thus a vast shell of gaseous matter very thin at its poles but of great perpendicular thickness in its equatorial parts, would become detached from the rest, and from its attraction for the material directly below it, in competition with the central nucleus which would draw it the other way, there would result a vast space between the shell and the central mass comparatively free from matter. The continued shrinking of the central mass would cause it to disengage a second shell in the same manner as the first, and this operation might be repeated a number of times. In the case of our solar system there appear to have been nine of these spherical jackets cast off. In the process of forming a planet from one of these hollow spheres, the swiftly moving bulky equatorial parts would gradually draw to themselves the smaller and slowly moving parts about the polar ends, a process which would

soon convert the spheroidal shell into a ring. These operations would tend to produce in different parts of the ring, regions of unequal density, the denser parts becoming nuclei, toward which the others would be attracted; that is while all parts of the ring were rapidly pursuing their way around their orbit, the distances apart of the condensed nuclei in the ring would not remain the same, and in the course of time the principal part of the matter of the ring might be absorbed in the formation of a single globe or planet. This globe might then repeat the example of the body from which it was formed, and thus cast off one or more shells which, passing through the same process form themselves into secondary globes or satellites.

Or the great ring, instead of becoming consolidated into a single globe, might become formed into numerous nuclei which all continue to revolve about the central sun independently of each other, forming thus a number of globes.

Or the ring might remain homogeneous and not form nuclei at all but gradually become contracted into dense matter, still preserving its annular shape. On the supposition that our solar system has been formed from the matter cooling gradually from an incandescent condition, nine of these gaseous shells have been formed in succession, the outer one comprising the material from which the planet Neptune and his moon were formed, the second one being that of Uranus, the third Saturn, the fourth Jupiter, the fifth the Asteroids, then in succession, Mars, Earth, Venus, and Mercury. In the cases of all the planets, except the asteroids, the shell became a globe; and in the cases of all except Venus and Mercury, these globes each threw off secondaries or satellites as follows: the Earth one, Mars two, Jupiter five, Saturn eight, Uranus four, Neptune one. Where a planet has more than one satellite, they are at different distances from their primaries as the planets themselves are from the sun. Besides his eight moons Saturn has two enormous rings; that is, Saturn has thrown off ten rings in all, and the outer eight of them have become globes, while the inner two have remained rings which have become exceedingly flat and thin. The ring thrown off by the sun between the orbit of Mars and that of Jupiter did not become formed into a single globe like the rest, but in cooling off collected around a vast number of nuclei which, instead of consolidating into one, have remained separate and independent. Two hundred and forty or more have been discovered, the largest being 1,400 miles in diameter, and the smallest probably less than a dozen, and there are no doubt thousands still smaller. The great width of the ring is shown by the fact that the distances of these planets from the sun range all the way from 210,000,000 to 300,000,000 of miles, showing the ring to have been at least ninety millions of miles in thickness from its inner to its outer edge.

That the solar system has been evolved from a state of incandescent gas in some such manner as this, is rendered probable by numerous facts. All the planets revolve around the sun in the same direction. Their satellites also revolve around the primaries in the same direction, with one explainable exception, and the sun and planets also revolve on their axes in the same direction. They also revolve in nearly the same plane, and their orbits are all nearly circular, thus differing from those of comets which are extremely eccentric, and which have a separate history of their own. There are, in the distant regions of space, vast numbers of nebulous bodies in various stages of condensation which are proved to consist of hot gases, and no doubt exhibit the preliminary conditions of future solar systems, and are examples of the former state of our own. This "*nebular theory*" of the evolution of the solar system, which can be merely mentioned in this place, is so extremely probable, and so well accounts for the facts, that it is the commonly accepted theory of astronomers generally.

The energy generated by the collision which produced the disintegration of the materials that have formed our system is, in considerable part, being lost by radiation into distant space. We may suppose it keeps on going till intercepted by other bodies, which it is certain to be sooner or later. It cannot possibly get beyond the limits of the ether, because it is the motion of the ether, and if it could not be delivered to other bodies capable of absorbing it and turning it into other forms of motion, we should have to conceive of the ether as forever remaining in a state of vibration; that is, there would be perpetual light and heat after all solid bodies had become too cold for further radiation. It is possible to conceive of a state of equilibrium like this, but since the infinity of past duration has not been sufficient to establish it, it must be concluded to be an impossible condition.

The energy not radiated away from the solar system takes all the different forms that are known to the physicist, the chemist, the biologist, and the psychologist, some of which we have been considering in the foregoing chapters.

We are informed by the astronomers that the comets, some of which come from regions far beyond the known limits of the solar system, are subjected to enormous extremes of heat and cold. Some of them approach the sun so closely that if they were composed of the most refractory materials we know of, they would be reduced to an incandescent vapor. The heat they encounter is vastly greater than that of our hottest furnaces. As they recede from the sun they gradually lose their heat, and in the distant parts of their orbits encounter the intense cold of space.

Our solar system, the sun with his whole family of planets, is proved

to be in motion toward the constellation Hercules at the rate of over 20,000 miles an hour, at which rate we ought to get there within a couple millions of years. In all probability our system travels upon a vast elliptical orbit like that of a comet, which, after periods of perhaps some millions of millions of years, brings us near enough to its great glowing focus to turn the solid matter of our system into an incandescent gas; in which condition we are allowed to rush forward upon the outbound portion of our orbit with ample leisure before us in which to cool off and re-enact the evolution of a solar system, with its rings and planets and moons, with all their possibilities of revolution and rotation, of land, water, and air, and of plants and animals.

All the motions of the heavenly bodies from a two-ounce meteor or a fifty-pound comet to Sirius, weighing fourteen times as much as our sun, are due to the attraction of gravitation. It thus appears that the *Force of Gravity* alone, operating in the reduction or annihilation of distances between bodies, is the cause directly or indirectly of all the forms of motion and energy with which we are acquainted.

There is no limit to human curiosity, and so we are not satisfied merely to know that gravity begets molar motion, and molar motion when arrested produces heat, light, sound, electricity, and other forms of molecular motion; we want to know *how* gravity operates.

If a cannon ball were carried up from the earth toward the moon it would get lighter and lighter, till at length a point would be reached where it would not weigh anything at all. Carried further, it would begin to have weight, and it would have to be supported to keep it from falling, not toward the earth, however, but toward the moon. At a particular point, therefore, the ball has changed its allegiance from the earth to the moon, and now apparently wants to go there. What has the moon done to inform the ball of her whereabouts, and inspire it with a desire to rush to her? Evidently she has done something, for if she were moved away you might continue to carry that ball in the same direction to the spot she had occupied 240,000 miles from the earth, and it would still have weight which, though diminished, would cause it to fall back to the earth as soon as liberated. When the moon attracted the ball away from the earth in our hypothetical case, it looks as if she threw out something like a lasso, or noose, or net, and drew it in, with the ball in it. And I take it this is precisely what she did do, and this is what the attraction of gravitation is. It involves a motion in two ways, a reaching out, and a pulling in. Before the ball could move toward the moon, some sort of connection or relationship must be established between the two. Otherwise we should be compelled to suppose some force, extraneous to both, to stand behind the ball and administer an impulse in the direction of the moon. But in that case

why should the impulse be in the direction of the moon in preference to some other direction? We find as a matter of fact that these preferences in direction are always settled in favor of the direction towards the greatest mass, provided distances are the same, and so we are bound to suppose a relationship of some sort between the attracting bodies to determine this question of mass, and cannot evade it by interpolating a third party or source of energy. If there is such third party, the relationship would have to be conceived as existing between the attracting bodies and it. So the conception of a third party does not help us. In any theory of gravity we attempt to frame, we are therefore bound to include the conception of a mutual interchange of communication taking place between two bodies, preliminary to the mutual pull they exert on each other. We cannot conceive otherwise, how, for example, in our hypothetical case above, the ball could reach a decision as to the relative mass of earth and moon, unless it were subjected every moment to an influence which every moment varied as the distances between the bodies varied, it being the fact that bodies weigh less to each other as their distances apart increase, and more and more as the distances diminish. That this communication is going on thus momentarily, is proved by the fact that no matter whereabouts on the road between the earth and moon the ball is liberated, it begins its fall towards one or the other at once. Assuming the mass of the earth to be 81 times as great as that of the moon, and their distance apart to be 240,000 miles, the point between the two at which their attractions for the ball would be exactly equal, would be 24,000 miles from the moon, and 216,000 miles from the earth. If the best surveying party that ever staked off a railroad, were to measure these distances, and try to locate this point, they could not be sure of it within many chains, or be able to guess on which side of the true spot they had placed it. But if the ball were to be set free it would be found to have the exact tally. Place it where you will, its apparent intelligence as to the direction of the heaviest mass is never for a moment at fault. Wherever it may be, it seems at every moment to be thoroughly posted, and never gets lost or "turned around." There is only one possible interpretation to this, and that is, that as a part of the machinery of gravitation, every body sends out an influence which, reaching other bodies, is the equivalent of a notification or intelligence of their whereabouts and their magnitude.

The sort of attraction or influence at a distance about which we have found out the most, is magnetic attraction. As explained in a previous chapter, a magnet appears to shoot forth a vast number of "lines of force," as they are denominated, which, upon reaching a definite distance from the magnet become deflected, and return to it, and other bodies caught in these return currents are drawn by them back to the magnet, a process which constitutes "magnetic attraction."

Then again in galvanic processes such as electrolysis, there seems to be a progressive movement of a substance from one place to another, a current in the true sense of the term. But in the radiation of light and heat, while there is not supposed to be a bodily movement of the ether in the form of a current, there is an advance of an undulatory movement of the molecules, beginning at the luminous body and spreading in all directions. So that a streak of light is a progressive succession of local molecular movements. Something similar to this has been suggested as the mode of the propagation of electrical attraction. A body positively electrified begins its inductive operations upon the molecules of ether next to it, by driving off the positive electricity in them to their further end, and attracting the negative electricity in the near end. The repelled positive electricty performs the same operation upon the next molecules, and so on. In case ponderable bodies are involved, the end next the original attracting positive body being nearer than the repelled end, the balance is in favor of attraction, and so the body moves toward the attracting body. It may be observed further that as the repelled electricity is always on the peripheral portion of concentric spherical shells, it must be less intense area for area, than the inner or attracted electricity. (See illustration of sound page 374). So that as between attraction and repulsion the balance is always in favor of the former.

Electrical repulsion takes place after a negative body has been attracted and held awhile in contact with a positive body, the presumption being that positive electricity is transferred to the negative body until it becomes more positive than negative, when the two being alike, repel. We do not see this repulsion as between permanent magnets and the bodies they attract. The armature of a horse shoe magnet is drawn to the poles and remains there for years. There is repulsion however, if poles of separate magnets having the same name are brought near each other. But it takes work outside of the bodies concerned to bring about such presentation of opposing poles. Thus there appears to be no difference in principle between electricity and magnetism in this respect, but the differences depend upon the bodies involved. *No body becomes either electrified or magnetized unless work is expended upon it.* The work expended upon most bodies in electrifying them by friction is soon expended in processes of repeated repulsion, or in the recovery of its former neutral condition by the electrified body. When work is expended in setting up magnetic action in a piece of steel, however, it is like setting a top to spin in a vacuum; it runs for a long time before the force is wasted. The attractive force of the magnet is limited to to the amount of energy expended in making a magnet of it, and if it be loaded with a weight which the same quantity of energy could raise

with a windlass or some other mechanical contrivance, it will hold it up, but will fail to hold any more, and when that which it thus holds up is pulled away from it, there will be restored to it as much force as was required to pull away the weight.

Now in looking among these phenomena of electrical energy, it is not difficult to discover those which are comparable with the phenomena of gravitation. Gravitation is like magnetism in the fact that its attractive force always overpowers its repulsive force. But compared with magnetism it is effective at an infinitely longer range, while magnetism is of vastly greater force at short range. The rapidity of electrical induction is practically the same as that of light, and probably the propagation of the influence of gravity is the same; but we have no means of making gravity cease and begin, as we have in the case of electrical phenomena, and so we never can find out how fast its influence travels. At any rate, however, no planet or sun has yet been found to travel fast enough to get away from its influence.

Now if we conceive every atom of ponderable matter to be a permanent magnet endowed with a power of attraction similar to that of magnetism, and with a power of induction like that of electricity, we have the substantial conditions of gravitation, and it becomes a sort of cross between magnetism and electricity. We have already attributed the phenomena of electricity and magnetism to movements imposed upon an imponderable ether, the same substance to whose movements in a different way, are attributed the phenomena of light and heat. In supposing gravity to be another form of motion of ether, we must conceive it as being the earliest and most elementary form. By means of heat we can destroy the magnetism of a steel magnet and it is not restored by simply being cooled off. But gravity cannot be annihilated by any means at our command. The force of gravity may be less or more, according to the distances apart of the attracting atoms, but it always remains and becomes appreciable when the distance is sufficiently reduced. We perceive then, that while as forms of motion, magnetism, electricity, heat, light, nervous action, &c., are in some degree equivalents of each other, and can be exchanged for each other, one entirely disappearing often in giving rise to another, gravity is subject to no such accident. When a body becomes magnetic or electric it does not lose its gravity. So that while the *force* of gravity comes and goes, the *property* never does. Compare this fact again with magnetism. The magnetic particle may not lose its property of attraction for a long time, although its force varies under the same conditions that affect the ponderable particle. Thus while gravity becomes a mode of energy quite as intelligible to us as magnetism, and presenting many parallels with it, its endowment appears to be perpetual instead of temporary like that of the magnet.

But have we any warrant for assuming gravity to be perpetual and therefore an original and necessary affection of matter? The alternative to this assumption is that it is an acquired affection like the magnetism of the magnet; and if acquired, then it must be like magnetism, the result of work done. And so we should reach the important conclusion that *gravitation is the result and expression of work done on imponderable matter.* That is, matter previously imponderable receives an energetic impact that sets up in it the motion gravitation, that abides with it thereafter indefinitely, and thus renders it ponderable. But such expressions as perpetual, indefinite, permanent, &c., are after all only relative. A permanent magnet will wear out in time, and the product of any work must in the nature of things be liable to become undone. That which has a beginning is liable to have an ending. And if gravitation is a result of conditions and the expenditure of work, it is not inconceivable that the work may in time become undone and matter again become imponderable.

But how can we conceive of work being done on *imponderable* matter? We certainly have no experience of anything of the sort, but still I believe we may conceive of matter possessing rigidity and elasticity, and consequently resistance without ponderability. Such a body might receive an attack and be affected by it, but it is difficult to see how such a body could make an attack.

A conception which appears to satisfy the conditions of original existence is that of matter in an extremely attenuated condition, yet possessing rigidity and elasticity, and endowed with a certain quantity of *motion.* From this state of things there would be differentiations intensifying and specializing motion in some parts, and reducing it in others, so that we should get matter endowed with energy in different quantities, and becoming ponderable in different degrees.

The least ponderable remains as ether, and becomes the vehicle for the transportation of the energy arising from the arrest of the motions of the matter endowed with weight. The substance ether is not to be understood as of uniform constitution everywhere, but it differs in density, being more rare in the interplanetary and interstellar spaces, and more dense in the intermolecular spaces, and in the close vicinity of ponderable bodies. There can be little doubt that many of the forms and tones of the various molecular energies depend upon these local conditions of the ether as to density, contiguity to other matter, freedom, confinement in the interstices, or intermolecular spaces of ponderable bodies. It is the movements of the condensed ether under different conditions in the different bodies, machines, and organs with which it becomes involved, that constitute the phenomena of gravity, electricity, magnetism, chemism, heat, light, sound, vitality, nerve action, sensation and mentality.

Some thirty years ago, Prof. Tyndall suggested that there is a condensed ether which surrounds the atoms, and that it may be the "vehicle of electric currents." Prof. Cooke also believes in the condensed atmosphere of ether surrounding individual molecules of ponderable matter. It is said that Faraday was the first who adopted the idea that electricity is the motion or tension of ether contained in or attached to solid or ponderable bodies.

Ether and Sound. In treating of sound in chapter 39, I have followed the account of it usually given by physicists in which no reckoning is made for any part which may be played by the ether. It has been observed in a great many cases that a certain rate of the vibration of ponderable elastic substances accompanies each pitch of sound, and a table of these rates is given in chapter 39. It has been shown that the ærial vibrations are conveyed to the ear drum and cause it to vibrate and to set the hammer and other bones in motion, which in turn communicate the jar to the lymph inside the canals and cochlea, and to the hairs and otoliths. All this motion of ponderable matter goes along from the sounding body to the very terminal fibers of the auditory nerve. But there it appears to stop; and the motion which goes on from there in to the brain is different. It is now a nerve current which is beyond doubt a mode of polar or electrical movement, being to the nerve fiber what the galvanic current is to the conducting wire. Now this is not essentially a motion of ponderable matter, but of the more or less condensed fluid ether, contained in the conducting nerve fiber. Now let us inquire how this motion of the ponderable matter, upon its termination as such in the ear, is succeeded by motion in the nervous ether. It is conceded by all, that the interstitial spaces of all ponderable bodies are permeated by the ether. Now when the elastic air is vibrating forth and back under an impulse from a sonorous body, I suppose the enclosed ether partakes of its motion, and in the mutual embrace with the heavy body, it is urged in all directions, and among others towards the ear. But it, like the heavy body, is elastic and mobile, and when the pulsations of both have reached the *crista acustica*, and those of the ponderable body are quenched in heat, supposing that to be their destiny, those of the ether, end in setting up the current in the fluid contained in the nerve. It is like the conversion of the tidal swell of the sea into the rushing flow of the tidal wave up the Bay of Fundy, or some other estuary. According to this hypothesis then, the jostle or pulsatory movement of the ether, the condensed ether surrounding the molecules and contained in the interstices of still more condensed ponderable matter, is the immediate antecedent cause of the current in the auditory nerve. But yet this jostle or pulsation of ether is accompanied up to the very entrance to the nerve by a like jostle or pulsation of heavy substances, the air, the ear drum, the bones, the fenestra ovalis, and the lymph. Weseem bound to conclude that this particular sort of motion of ether depends on its affiliation or alliance with

heavy matter. And further it is proved that this sort of motion cannot be taken on by the uncondensed ether which pervades space, and whose undulations cause light and heat, by the fact that sound cannot cross a vacuum. There being no ponderable matter in the vacuum, there is no *condensed* ether, consequently no pulse.

It is *said* that the velocity of sound is increased by the elasticity of its medium, and decreased by its density. In gases the velocity increases with temperature. In general terms the velocity in gases is directly as the square root of the pressure they are under, and inversely as the square root of their specific gravity. The following are velocities of sound in feet per second, in the substances named: lead, 4,030; gold, 5,000; copper, 11,000; iron, 16,822; cast steel, 16,354; alcohol (at 20° centigrade), 4,218 feet; ether (0° c), 3,801; sea water (20° c), 4,768; fresh water (15° c), 4,714; oxygen (0° c), 1,040; carbonic acid, 858; hydrogen, 4,164; air, 1090.

Now the question arises, is the movement of the pulse through the interstitial ether, invariably accompanied by a corresponding synchronous vibration of the ponderable body? Is it not conceivable that the vibratory pulsations of the enclosed ether may in some bodies outrun the capacity for vibration of the body enclosing it?

It is stated that the velocity of sound in a steel rail is fifteen times as great as in the air, so that at a point 1,090 feet from the place where a sound originates, it would be heard 225 times as loud by way of the rail as by way of the air. The physical basis of loudness is amplitude, and amplitude is the fulness or wideness, or in the case of sound we may say the *longness* of the movement of the matter engaged in producing a wave. The length of the wave of the small octave C, having 132 vibrations per second, is in air 8¼ feet and its amplitude is the distance which the further end is driven away from the sounding body at each pulsation. That is, a ray or spoke of air so long, is driven endwise a certain distance, which distance constitutes its amplitude. Now in steel the length of this wave or spoke, for the same sound, is nearly 124 feet. The amplitude in the example given above is 225 times greater than in the air. Are we to understand that the molecules of 124 feet of the steel rails are driven endwise against each other, so that the end one in each wave moves 225 times as far as the molecule of air at the end of an air wave, when both are started by the same impulse? It does not seem reasonable. Again, a sound just loud enough to be conveyed by the air a distance of 1,090 feet, or about one-fifth of a mile, will be conveyed by the steel rail about three and one-tenth miles. Now when we are told that under the impulse of the sonorous stroke all the air is vibrated to a distance of one-fifth of a mile only, while all the particles of steel in the conductor for a distance of three and one-tenth miles are vibrated by the same stroke, it does not look reasonable. Again, one may hear the chirp of a cricket in the next room, although separated from it by a brick wall a foot thick. Does the vibration communicated to the air by the cricket jar the bricks and mortar of the masonry? Numerous experiments and observations do indeed show

that a jar is communicated to the air when a sound is made. Mention has been made of the transfer of vibrations through the air to piano strings, resonators, and the like. Prof. Tyndall exhibited an interesting experiment as follows. A sort of drum is made by stretching tissue paper over a hoop, and on its surface is sprinkled a light layer of sand. A second instrument is made by taking a stick a yard long, and attaching each end of it to the center of a thin bronze disc, the whole resembling two wheels joined by an axle. Now holding the stick in one hand in such position that one of the discs faces the paper drum, rub it up and down with a rosined rag. The shudder given to the stick is communicated to the discs, and thence to the air, and finally to the paper drum which starts into musical vibrations, accompanied by a a dancing movement of the sand which is soon shaken into concentric rings occupying the positions of no vibration. Again, if a cannon be fired in the neighborhood of a house, the concussion of the air is apt to break out the glass on the side next to the gun. Sounds are most commonly, though not always, originated by a stroke or blow made by one ponderable body upon another. The vibration of one or both the striking bodies certainly takes place, and may be communicated to a third body, provided it possesses a like fundamental. But it is important to observe that when the fundamental of the third body is not the same it will still convey the sound through its molecules, although it will not vibrate; while if it have the same fundamental it will vibrate and "reinforce" the sound, as it is called. If you strike a brick wall with hammer it gives a dull sound which is due to its fundamental, but when you hear the cricket through it, I hold the sound is not conveyed by the vibration of the bricks and mortar, but by that of the enclosed ether. A study of the telephone may throw some light on this subject. The construction of the telephone involves the principles, (1) that there is a magnetic field about every magnet, (2) that the state of the field is affected every moment by the activity of the currents in the magnet, and (3) that under certain conditions the current may be made to fluctuate in strength. The telephone consists essentially of a transmitter and a receiver connected by a wire. In the Bell telephone these two are just alike, and a description of the transmitter answers for the receiver too. (See fig. 400.) There is a tube of wood or hard rubber, one end of which is closed by a thin iron plate two inches in diameter, and called the diaphragm. This is placed near the mouth when it is talked to or near the ear of one listening. Inside the tube is a straight cylindrical steel permanent magnet, one end coming forward almost, but not quite far enough to touch the diaphragm or disc. Around the forward or disc end of the magnet is a small bobbin wound with a coil of fine insulated wire, the ends of the coil terminating in the wires

marked *c* in the figure which run back to the bind screws *d*, where they connect with the main circuit. No battery is required in this instrument, the magnet of the transmitting instrument inducing the needful current to act upon the magnet of the receiver. According to S. P. Thompson the theory of this instrument is as follows: "The magnet *a*

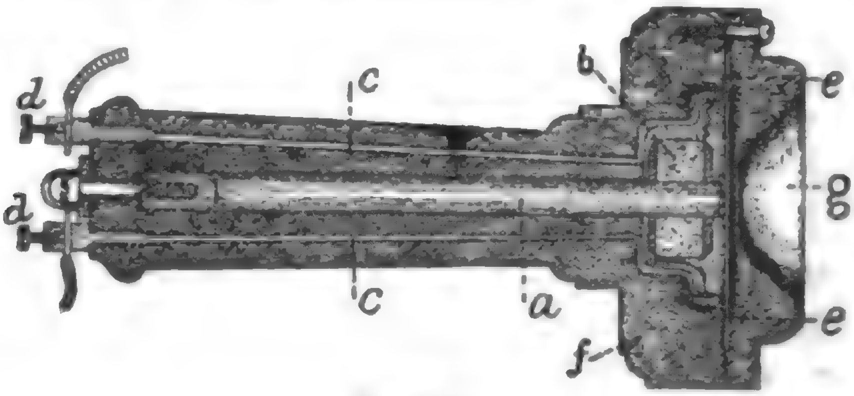

FIG. 400.

Figure 400.—*Section of a Telephone.* *a.*—Steel magnet. *b.*—Bobbin of wire on the end of *a.* *c.*—Wire from the bobbin to *d.* *d.*—Binding screws forming connection with the general circuit. *e.*—The vibrating diaphragm. *f.*—The external wooden or rubber case. *g.*—The mouth piece with hole at the bottom opening on the diaphragm.

induces a certain number of lines-of-force through the coil *b*. Many of these pass into the iron disc. When the iron disc in vibrating moves toward the magnet pole, more lines of force meet it; when it recedes fewer lines of force meet it. Its motion to and fro will therefore *alter the number of lines-of-force which pass through the hollow of the coil b*, and will therefore generate in the wire of the coil, currents whose strength is proportional to the rate of *change* in the number of the lines of force which pass through the coil." (See ch. 36 for explanation of "lines-of-force.")

Dr. Konig showed that if the diaphragm be removed, and a tuning fork set in vibration near the end of the magnet, the disturbance of the lines-of-force takes place the same as with the vibratory disc, and a fork of the same pitch, or differing by octaves, when placed near the magnet of the receiving instrument from which the disc was also removed, took up the vibration and gave its fundamental sound. Moreover if the circuit be broken so that the vibration of the fork does not set up currents it will continue to vibrate a much longer time than when the circuit is closed and it is encountering resistance and doing work. In short we see here the same principle as that involved in the action of the dynamo. The telephone is in fact a sort of dynamo. But it is a dynamo of such delicacy that its currents are generated and fluctuated by exceedingly small disturbances of the field of its magnetism.

It is commonly explained that this disturbance is due to and exactly corresponds with the vibrations of the disc or diaphragm of the transmitting instrument. But now the question arises, is this vibration of the heavy body the real final cause of the disturbance of the magnetic field, or is it not rather caused by the accompanying movement of the condensed

ether belonging to and about the disc of the telephone, or the rotating armature of the dynamo? The magnet is a body which constitutes the home, harbor or den of a quantity of partially condensed ether. At the time the steel was magnetized this ether was set to moving with a wonderfully persistent motion, the movement being partly inside the magnet, and partly in the field surrounding it. Now when an armature or a diaphragm containing a quantity of similar ether having a like fundamental tone, is pushed into the field of the magnet, *that half* of the motion of the magnetic ether that is *outgoing* resists the push and sends the ether of the armature back upon itself, making the momentary short current or jerk. When the armature is pulled away again, its ether being caught in the return or *ingoing* half of the ether of the magnet, the pull is resisted, and a short current or jerk takes place in a direction opposite the first. The magnet loses none of its force by this operation, but the alternating jerky currents are at the expense of the energy that moves the armature. The action with the armature is like a man in a boat alternately pushing and pulling himself from and to the wharf, and thereby creating currents in the water. The currents are at the expense of his own energy.

Since there is ether in all bodies it might be asked why any other substance might not do for an armature as well as iron. Iron is best adapted for the armature of a dynamo probably because its ether is of the density and tone best adapted for encountering the resistance of the ether of the machine, and the rest of the circuit. At all events the essential point is that the current is set up by the ether introduced into and withdrawn from the circuit, and not by the iron which goes along as its carrier. If this is the case, it is reasonable to suppose that other means might exist for setting up the motion of the ether in a circuit beside flourishing an iron armature through it. The metallic disc of the Bell telephone, as observed before, does not touch the magnet but is supposed to shake itself within the magnetic field, the ether attached to it alternately encountering the outgoing and ingoing currents of the magnet, and delivering the motions to the ether of the wire in the circuit. But it appears that the agitation may be communicated from a vibrating body to the air, as in the case of the microphone, and then as may be inferred, it is the ether contained in the air which disturbs that of the circuit.

In the case of the microphone, figure 401, the ticking of a watch or the perambulation of a fly on the instrument, is supposed to agitate the air and cause the spring to vary the pressure by which the buttons of carbon are held together, and so by making the connection alternately, more complete and less complete, the current is made to vary. The same principle is involved that governs in the case of the dynamo, and

the Bell transmitter, the pressure in this case operating to cast into the circuit, or take out of it a greater or less amount of the ether. The delicacy of the microphone is so great that the footsteps of a fly on the sounding board are heard at a distance much louder, than with the un-

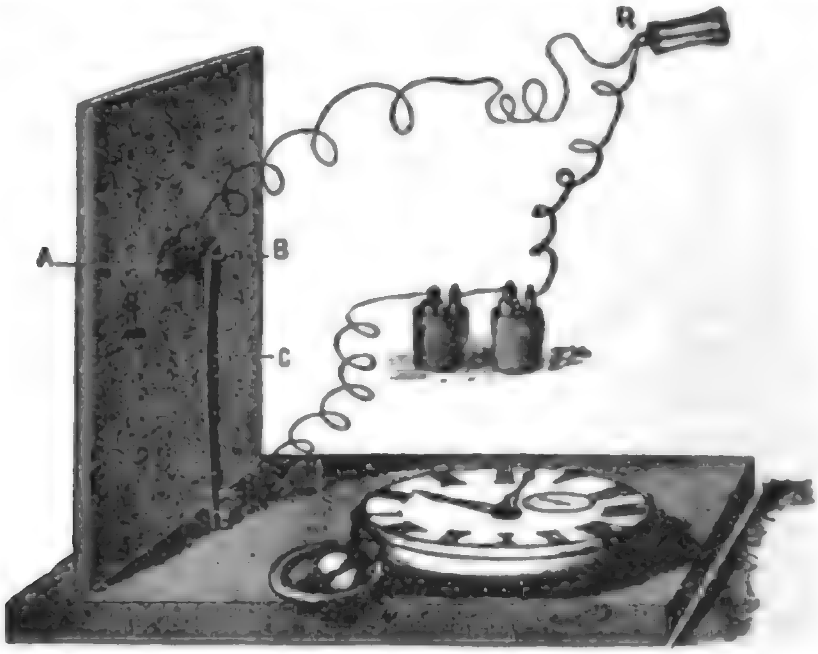

FIG. 401.

Fig. 401.—*Microphone.* It consists of a bottom piece and a thin upright sounding board of pine. A.—Button of carbon attached to the sounding board. B.—Button attached to a steel spring C which is fastened to the base board, and presses the two buttons together. R.—Receiving telephone, connected in circuit with a small battery.

assisted ear near by. The ordinary theory of the propagation of sound in solid bodies, involves the hypothesis of the change in the shape of the molecules under the sonorous impact. This is shown in figure 402. The action of the microphone is usually explained on the theory that the molecules of the carbon buttons are alternately shortened and lengthened, thus varying the resistance to the current, which passes more readily through the compressed than through the elongated molecules.

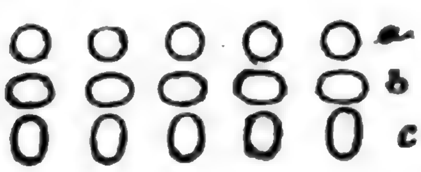

FIG. 402.

FIG. 402.—Showing supposed change in shape of molecules of solid body under the impact of sonorous impulses.
a.—Normal shape of molecules.
b.—Shortening and widening under the condensed pulse.
c.—Lengthening and narrowing under the rarefied pulse.

In experiments cited in Journal of Franklin Institute, volume 107, page 402, a microphone was used as a transmitter, and a metronome (of regular beats) for a sounder, and a Bell telephone for a receiver. Take off the diaphragm and mouth-piece of the (receiving) telephone and replace it with a glass plate. Then apply the ear and listen to the strokes of the metronome, and mark their force, then raise the edge of the plate by degrees and the sound differs but little, even when the glass is on edge, so long as it touches the case; but if it is raised clear from the case, no sound is heard; but touch the case again and it is heard

"With a plate of iron the strokes transmitted are much stronger and have a particular sound which diminishes rapidly in proportion as you raise the plate," and enfeeble the influence of the magnet on the iron; when touching the case edgeways it becomes like glass or wood, or other non-magnetic substance. It is inferred then that in the receiver "the iron diaphragm is subjected to a double influence, that of the magnet and the case in which it is fixed."

Du Moncel attributes the effects of the telephone to molecular vibrations of the magnet, which are strengthened by the iron diaphragm and rendered more sensible to the ear. "By raising the mouth-piece and the iron diaphragm of the telephone, and holding it firmly in the one hand, and with the other drawing a violin bow lightly upon the edge, you obtain a sharp sound that can be heard clearly in the receiving telephone. A small ruler placed crosswise before the instrument and passing beyond it some centimeters, produces a sound when struck at the end with the bow, so that when it is shortened the sounds are elevated, and give those of an ascending gamut, which immediately come to the ear at the receiver." The *grave* notes which shake the instrument, and the hand, are *not* heard in the receiver, while the sharp ones are reproduced there easily, and "the reason perhaps is because the vibrations from the sharp sounds approach to the character of molecular vibration." Strokes made on the magnet, the coil, or the case, were heard in the receiver. "The effects from the telephone are *too usually* attributed to the *sensible vibrations* of the iron plate moving backward and forward from the magnet, representing the well-known and habitually accepted action; but the *molecular vibrations* which are performed, so to speak, atom by atom *in* the immovable plate, play a more important part, and without them articulate speech would be impossible."

Now, in explaining the foregoing, I think everyone will admit that the electric current which runs through the wire from transmitter to receiver, consists of a movement of the ether contained in the wire and not the particles of the wire itself. No sort of movement communicated from particle to particle of the iron wire could be imagined to be competent to get around the world in a few seconds. This movement of the current ether in the wire then communicates motion to the ether in the receiving diaphragm, to the case of the instrument and to the air, and finally to the ear. In the auditory nerve and ear we recognize the motion as certainly molecular and ethereal. Having thus ethereal motion *in* the wire of the instrument, and *in* the ear, and having, (as all agree) an unbroken succession of ether *from* the instrument *to* the ear, there is certainly nothing violent in the claim that this ether itself is the real vehicle of the movement from beginning to end; the motion "from atom to atom" in the receiving plates mentioned above being in reality a mo-

tion from one molecular *space* to another, and communicated from the spaces in the metal or other hard parts of the receiving telephone to the spaces in the air, and thence to the ear, &c. It is nothing against this view if this movement of the ether carries with it a greater or less movement of the ponderable matter, the wood of the case, the air, the ear drum, &c., with which it is so intimately associated. A pretty good illustration of the manner in which I conceive the ether to be associated with ponderable matter may be got by filling a tooth brush with water. If turned over on its back the water will stand amongst the bristles to their full height, and it is easy to see how a jar communicated to the water would affect the bristles as well, and vice versa.

According to this hypothesis, then, sound depends upon a peculiar jostle or thrust of more or less condensed ether of a consistency only found in association with ponderable matter. This motion may be communicated to it, and commonly is, by the motion of the ponderable matter it belongs to; and it may be synchronous with vibrations of such matter, or it may outrun and become independent of them, going at a rate and to a distance not possible to vibrations of the ponderable body; for example (I should say), as in the case of sounds conveyed by the earth; or it may arise, as in the experiments mentioned above, as the sequel of current electricity, such current being periodically and suddenly arrested in part, and its influence on the ether in the magnet, and its field, being reduced to the ejaculatory motion which results in sound. It is in accordance with well-known laws of mechanics that we may conceive the ether confined in the intermolecular spaces of ponderable bodies to be subject to reactions against the impact of force, different from those of free or interplanetary ether. If you take a pine stick one inch square and one foot long, and stand it on one end, it will easily bear the weight of a man placed on its top. But if you make the stick 50 feet high, supporting the top with guy lines to prevent falling, it will bear scarcely any weight without springing to one side in the middle; "buckle," as it is called. But if its "buckling" be prevented by means of numerous guys, it will sustain the weight of a man the same as the shorter piece. If blows be substituted for weights in the experiment, corresponding effects will be observed. And so we may conceive that when the ether confined in the intermolecular spaces of ponderables receives a thrust, it has less chance to buckle than where it is not thus supported. This consideration coupled with that of an increased density in the intermolecular ether, accounts for the greater wave length of sounds in such bodies as steel, copper, water, &c., without the necessity of including the movement of the ponderable particles themselves, when the finest microscopic observations fail to discover any such movement.

(Sound travels in hydrogen about four times as fast as in air, which is generally explained to be because hydrogen is so much *lighter* than air. Air is 14½ times as heavy as hydrogen. But it travels faster in water than in hydrogen, and water is 11,160 times as heavy as hydrogen, and it travels in iron about 15 times as fast as in air, while iron is 81,500 times as heavy as hydrogen!)

A comparison between the action of the telephone and that of the natural ear shows not merely analogy but virtual identity. But it is the same if we consider any sonorous body. When a bell rings, the stroke of the hammer sets up a vibration in the metallic particles of the bell, and at the same time the ether of the hammer hurled into the field of that of the bell creates a corresponding disturbance there. Both these disturbances carried side by side through the air, reach the auditory nerve. It is hard to tell just what becomes of the energy of the vibrations of the ponderable bodies, whether they assist the action of the nerve or are reduced to heat; but it is reasonably certain that the movement of the ether terminating in the final cells of the auditory ganglions of the brain constitute there the sensation of sound. Thus, it is the pulsatory motion of the ether in the bell that sets up a corresponding motion of sound in the brain; as it is an undulatory motion of the ether reflected from the outside of the bell that sets up the corresponding sensations of sight by which we learn its form. If the bell be hot, as when first cast, we get a knowledge of that also by the undulations set up by its agitation in its surrounding ether, and the possible participation of the intervening air in this effect is seen to be incidental and not essential to our sensation of heat.

Ether and Smell. I propose also to introduce this hypothetical condensed ether into the theory of smell, taste, touch, and chemical reactions generally. Smell depends upon the fact that infinitessimal particles of a volatile body are cast off, and riding through the air, alight on the pituitary membrane, and there set up a chemical action which produces a nervous current to the brain, which ending, in turn, becomes the sensation of smell. Now on the hypothesis that each particle is surrounded and permeated by its quota of condensed ether, we may suppose a repulsive movement of a chemical or electrical nature to drive off a portion of this ether which carries off with it the delicate particles of its volatile associate. Upon reaching the pituitary membrane, the adventitious ether sets up a disturbance of that belonging to the organ, which results in a current up the olfactory nerve. The operation here is apparently analogous to that which results in sound. We have the action of a connected succession of the ethereal substance all the way from the odorous body to the olfactory lobe.

In *Touch and Taste* too, the same principle is involved, the disturb-

ance of the ordinary state of the ether of the tissues beginning at the surface of the skin and the taste papillæ respectively.

Chemism and Ether. The theory of chemical attraction is not yet settled, and there are various opinions. The opinion expressed in Cooke's chemistry is that the atoms or molécules of the elements are polar, in much the same way as metals and other bodies are magnetic or electric. With some molecules the polarity is inherent and permanent, and with others it can only be induced by causes outside of themselves. The last, answer to bodies called neutral in respect to electrical attraction. Steel can be made into a permanent magnet, iron cannot. But if polarity is induced in iron by the steel magnet, it becomes a magnet while under this influence of the steel, but ceases to be one as soon as such influence is withdrawn. In like manner Prof. Cooke supposes the action of chemical polarity is inherent in some bodies, and induced in others. "Again, different substances are susceptible to chemical polarity to very different degrees, and the susceptibility varies under different conditions. The chemical activity of a substance then depends on the degree of polarity inherent in its molecules. The active qualities of acids and alkalies show their molecules to be strongly polarized, while the inert character of most elementary substances is explained by the neutral condition which their homogeneous structures would naturally produce in their molecules. For example, suppose every molecule of sulphuric acid, H_2SO_4, or of hydrochloric acid, HCl, or of sodic hydrate, $NaOH$, is naturally polarized, while on the other hand the molecules of zinc, Zn, magnesium, Mg, hydrogen, H-H, and of oxygen, O-O, are normally neutral. As soon, however, as we place zinc in contact with dilute sulphuric acid, the metallic molecules become polarized by induction to the degree of which they are susceptible under the influence of this acid. A powerful attraction is thus developed in which the familiar chemical action is the result. If magnesium is treated in a similar way the action is more energetic because, as we suppose, the molecules of this metal are susceptible to a higher degree of polarity, and the force developed is proportionally stronger. On the other hand, with metallic copper, there is no action under the same conditions because the molecules of the metal do not acquire a sufficient degree of of polarity to determine chemical change."

Atoms of the different elementary substances are recognized by chemists as possessing a different number of points of union or poles, by which they are attached to other atoms. These points are called bonds, and the atoms possess these bonds from one to seven or eight in number. Atoms are classified according to the number of their bonds, and graphically shown in figure 403. The names, from the Greek, signify numbers which allude to the bonds or poles.

Hydrogen, fluorine, &c., are monads. A hydrogen atom therefore cannot be joined directly to more than one other atom. Oxygen is a dyad and has two bonds so that one oxygen atom may be attached to two hydrogen atoms, forming a molecule of water, the formula being H_2O, and graphically expressed H-O-H, showing two bonds to the O, and one to each H.

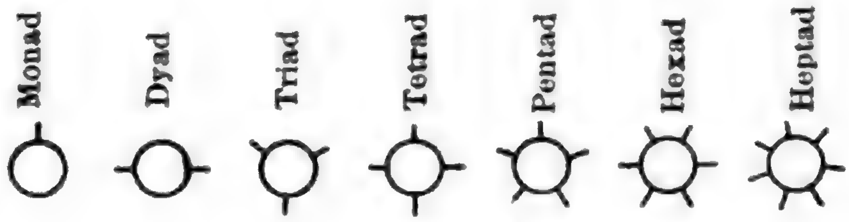

FIG. 403.

The number of bonds or poles possessed by an atom is the measure of what is called its *valency*, which indicates the number of other atoms with which it can be directly joined. Thus H F, H Cl, H Br, and H I are molecules of Hydrogen fluoride, Hydrogen chloride, Hydrogen bromide, and Hydrogen iodide, in which one monovalent atom of Hydrogen is joined to one atom of Fluorine, Chlorine, Bromine, and Iodine, respectively. H_2O, H_2S, H_2Se, H_2Te, stand for molecules of Hydrogen oxide (water), Hydrogen sulphide, Selenhydric acid, and Tellurhydric acid, in which two atoms of monovalent hydrogen are joined to divalent atoms of oxygen, sulphur, selenium, and tellurium, respectively. H_3N, H_3P, H_3As are molecules of Hydrogen nitride (ammonia), Hydrogen phosphide (phosphine), and Hydrogen arsenide (arsine), which are composed of three atoms of Hydrogen, and one each of trivalent nitrogen, phosphorus and arsenic. H_4C and H_4Si are molecules of Hydrogen carbide (methane) and Hydrogen silicide, composed of four atoms of Hydrogen and one each of tetravalent carbon and silicon, respectively. The graphic expression of one of these formula would be made by a tetrad atom, having a monad atom impaled on each of its four poles; thus

```
   H
   |
H—C—H
   |
   H
```

In the possession of multiple poles of chemical affinity, molecules imitate the masses that exhibit multiple poles of magnetic attraction. Multiplicity of polarity is no doubt due to the shape of the body, a mass having four poles has no doubt four corners.

Again there is a great difference in the force of chemical attraction. Some elements have a strong affinity for one another, others have weak affinity for each other, and still others have no affinity for each other at all. Oxygen forms a strong affinity with phosphorus, potassium, &c., nitrogen and carbon form weak affinities with hydrogen; chlorine and iodine, &c., have weak affinities for each other, while oxygen and fluorine, hydrogen and chromium, hydrogen and sodium, &c., have no affinity for each other at all. In this too we find the parallel between the magnetic attraction of masses and the chemical attraction of molecules, no two bodies being alike in their electrical characteristics, and neutral bodies being indifferent to each other. The theory was proposed by Berthollet, and has since been verified that chemical action depends on the mass of the elements engaged, as well as upon affinity. As he stated it, "Every substance which tends to enter into combination acts in proportion to its affinity and its mass." He regarded this as evidence that chemical affinity is essentially the same as gravitation,

But the force of all polar attractions are also in proportion to the mass of the polarized matter engaged. That what is called mass-action results from a sort of magnetic polar force rather than gravity, seems to be proved by the phenomenon of equilibrium which occurs in many cases. If, for example, alcohol and acetic acid be brought together, they begin to unite in the formation of acetic ether and water. But when this process goes on for a time it stops, because the ether and the water already formed become a bar to further action.

In a voltaic cell constructed by inserting in a vessel partly filled with dilute sulphuric acid, a plate of zinc and another of platinum, the top ends of the plates being connected by a wire as in figure 404, the acid

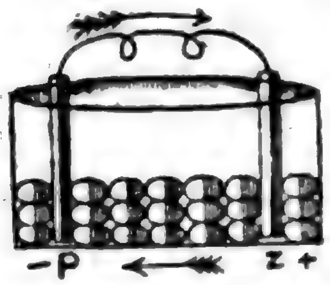
FIG. 404.

FIG. 404.—*Voltaic Cell.* The globules represent molecules of sulphuric acid H_2SO_4, their shaded ends being the sulphur, negative to the unshaded hydrogen ends.

is regarded as a permanent magnet, while the metals are neutral bodies. As soon as the metals are placed in the liquid, the magnetism of the acid induces tensions in the metals, and when the metals are joined at the top by a wire, these tensions give rise to currents (see page 331). As in this case the magnet is a fluid, it travels to the attracted body instead of the attracted body to it. And so we find the hydrogen portion of the molecules of the acid torn off and carried to the platinum plate where they remain in the form of small bubbles, or escape to the air, or enter into composition again; while the sulphur portion of the acid is pulled the other way and unites with the zinc, forming zinc sulphate (white vitriol), $ZnSO_4$, which remains in solution in the fluid.

According to Ohm, this movement of ponderable matter through the fluid is continued through the metals by an oscillating movement of lines of atoms, thus forming a continuous circuit of moving matter returning upon itself. The current doubtless has an effect on the molecules of its conducting wire, but the movement of such molecules is certainly *not* electricity. The essential movement is that of the ether in the acid to begin with, which secondarily sets up the movement of the ether in the metals. The ether in the acid is in motion from the time the acid is manufactured, and is the result and continuation of the work done on it then, just as the action of the steel magnet results from work done on it.

It is interesting to observe that sulphuric acid occurs free in nature in certain mineral springs, and in some rivers. It is said the Rio Vinagre in South America discharges about 84,000 pounds daily. Oak Orchard Spring in New York contains about 36 grains to the quart. It is found in the saliva of certain mollusks, some having as much as 3½ per cent. of it. It is also represented in various minerals, sulphates

of iron, calcium, barium, and strontium. (Barker's Chemistry p. 152.) Compare this fact with what is said on page 232 in regard to the property of sulphuric acid as a ferment. The fermenting power both of the sulphuric acid and the soluble ferment is due to their polar energy. Moreover the occurrence of the acid free in nature suggests its probable agency in the evolution of organic, from inorganic life.

That chemical affinity is not an original inherent property of matter, is proved by its dependence on heat. An affinity which a body has at one temperature is completely lost at another. Thus sulphuric acid at certain temperatures will, from certain compounds, drive off and take the place of phosphoric acid or boracic acid. But at very high temperatures either of these is more powerful than sulphuric acid, and the latter is evaporated and driven off while the former remain to enter into the combination.

But at extremely high temperatures all chemical attraction is nullified, and all bodies pass into the condition of gases. If steam be heated to a temperature of 3,000° C, it ceases to be steam, and the hydrogen and oxygen no longer remain united, but are resolved into their elementary atoms, or into hydrogen molecules and oxygen molecules. While thus dissociated, the hydrogen has been separated from the oxygen through a porous partition, but if the gases are allowed to cool together they will reunite at a lower temperature. Liquids and solids likewise undergo dissociation as well as gases. Some liquids become dissociated by simply warming, while boiling effects the dissociation of many liquids and solids. When any body is made volatile, it is dissociated. Many bodies of all three kinds, gaseous, liquid and solid, renew their combinations upon cooling after they have been dissociated by heat. We may suppose that the shapes of the elementary atoms have not been destroyed, and that when a reduction of temperature takes place again, a part of the heat is absorbed in giving motion to the ether belonging to them, and thus re-establishing their attractive affinity. "The valence of elements decreases with the increase of temperature." Thus at the ordinary temperature phosphorus unites with chlorine to form phosphorus-pentachloride PCl_5, and phosphorus is then said to be quinquivalent. But if the temperature be raised, the phosphorus becomes trivalent, PCl_3 and Cl being formed from the first named compound, the increase of heat nullifying two of the polar bonds. Great heat is the antagonist of chemism. At very high temperatures all chemical bonds are dissolved. But the "valence of an element may be constant towards some elements and variable toward others. Thus the valence of the members of the chlorine family towards hydrogen and towards most of the so-called metals is constant, while towards oxygen and towards hydrogen and oxygen together, it apparently varies between

one and seven. The valence of sulphur towards hydrogen is constant, but towards oxygen and towards hydrogen and oxygen varies from four to six, and towards chlorine from two to four."

Different sorts of bodies are very differently affected by the same temperature. A temperature low enough would make every body a solid, and one high enough would make every one a gas. At the ordinary temperature as observed by Gage, every solid may be regarded as frozen matter, every liquid as melted, and every gas as matter in a state of vapor. Air, that is oxygen and nitrogen have been frozen under a great pressure, and alcohol has been frozen.

We thus reach the conception that these different states of bodies are due to, and are an indication of different degrees of energy that have been expended upon them. When the earth was first formed, so much energy had been expended upon it that it was all in a state of incandescent gas. A great part of that energy has been radiated away, and that which remains of it affects chiefly the interior of the earth, which is still, no doubt, in a molten state. But the condition of bodies on the earth's surface is largely determined by the action of the sun. If it were not for that, all the water on earth would soon be ice, and even the air would be frozen into chunks. The water is mostly fluid and partly vaporous, and the air is gaseous, because the sun's energies drive the molecules of these bodies apart, and it is by a constant exertion of these energies that they are kept in the same average state from age to age. We are to understand then that a body is solid because its particles or molecules are comparatively close together; although in the most solid of bodies the spaces are of far greater extent than the molecules of the body. The reason that the spaces are as large as they are is that the energy applied to the body sets up a motion among its molecules, and they, by their activity, drive each other apart to distances corresponding with the degree of energy of their movements. In liquids the activity of the molecules is greater, and the intermolecular spaces are greater. In gases the activity of the molecules is still greater and the spaces still larger. It is estimated that the spaces in a gas are 1,000 times more extensive than the mass of particles of the gas. These spaces increase with the temperature, and the temperature is likewise a measure of the outward pressure of a gas, and the pressure is due in turn to the velocity of the movement of the particles or molecules. This velocity is very great and it has been calculated for a number of gases. At zero centigrade the velocity of oxygen molecules is reckoned at 1,512 feet per second, nitrogen 1,614, hydrogen 6,048. When the temperature is reduced nearly to that at which these gases are liquified, these molecular velocities are considerably reduced, but are still great. For oxygen at —119°c the velocity is 1,135 feet per second, nitrogen at

—146°, 945 feet, and for hydrogen at —220°c is 3,126 feet[1]. The number of particles in all gases at the same pressure and temperature is precisely the same. The number in one cubic centimetre of air has been estimated at twenty-one times the cube of a million (21,000,000,000,-000,000,000). As the activities of the particles cause them to collide with each other from four to ten thousand million times per second, the average length of the path they traverse before they strike and rebound from each other is very short, less than the ten-thousandth part of a millimetre ($\frac{1}{254000}$ of an inch). Knowing the number of molecules to a given volume, it becomes possible to calculate the absolute weight of a molecule, and this has been ascertained to be for hydrogen somewhere near $\frac{4}{1\,000\,000\,000\,000\,000\,000\,000\,000}$ of a gramme.

The transportation of the energy by which these molecules are driven and kept asunder, is by means of the ether. A hot body, as the sun, communicates its motion to the ether, which delivers it to the molecules of the gas. It must be therefore, that it is the ether among the molecules which first receives the agitation, and whose consequent motion compels that of the molecules themselves. It may be conceived, in fact, that the undulations continue into and through the body of the gas, and that the momentum of the energy thus communicated by these undulations to the ponderable molecules keeps up the motion for a time after the original energy has ceased to act. In a balloon of gas, subject to an ordinary temperature, we may suppose the undulatory movements to penetrate in all directions, and hence the motions of the molecules to be in all directions as is required by the fact of the equal pressure of the gas on all sides.

We may suppose that the different selective affinities in chemical combination are due to the agreements in the vibration of the ethers of the bodies involved, the force of the attraction being greater in proportion to the harmony of the vibrations. In the case of neutral bodies we may suppose their ether is at rest, but from the shape of the body it is connected with, it is endowed with a fundamental of its own which causes it to become active when operated upon by a force of its own pitch; and when thus active, an attraction occurs between it and the body exciting its activity. In this respect as well as others the parallel between chemism and magnetism is close.

Catalysis or Contact Action of platinum and other substances was mentioned on page 233. This action, which is due to the mere presence of a third body that does not itself appear to undergo any change, promotes a union which otherwise would be sluggish or impracticable. It is usually explained that the presence of the third body, as the platinum, causes the condensation of gases so that their particles are brought

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[1] See Lothar Meyers' Outlines of Theoretical Chemistry p. 156.

closer to each other, and thus within reach of each other's attractive influence. Thus hydrogen and oxygen may be mingled together without being chemically combined, but if platinum be then introduced they combine in the formation of water. Now if the molecules of the gases are held apart by their activity, or the force of their velocities, it must be that the platinum in some way reduces this activity. A ready explanation is that the fundamental pitch of the ether of the platinum is such as to interfere with the vibrations of that of the gases, by which they are checked, and the molecules thus allowed to fall closer together. After thus getting within reach of each other's attraction, they fall the rest of the way and the energy of their vibrations is turned into heat, a large quantity of which is evolved when water is formed.

There are some reactions in which a third party is employed, in which it is shown to have taken an active part, and yet come out just as it went in, without having, on the whole, either gained or lost. The third body in such cases is called a carrier. It was pointed out on page 178 that the red blood corpuscles are carriers of oxygen from the lungs to the interior tissues of the body. There are numerous other carriers of oxygen; nitric oxide NO is a carrier in supplying oxygen to the sulphurous oxide SO_2 in the manufacture of sulphuric oxide SO_3. The NO takes oxygen from the air, becoming nitric peroxide NO_2; then it is exposed to the action of SO_2, which gets away the acquired oxygen, reducing NO_2 back to NO, and becoming itself SO_3. The addition of water H_2O to this makes H_2SO_4, sulphuric acid. Sulphates and other compounds of iron, copper, manganese, and other metals likewise take up oxygen from the air but give it up to solutions of sulphurous oxide, and may be made to repeat the operation indefinitely. There are bodies too that carry chlorine in the same way, by taking it from one and giving it to another. The probable action of the carrier in such cases is much the same as in catalysis. The carrier first reduces the velocities of the body to be carried, which reduction brings it within reach of the attraction of the third body. Thus sulphurous oxide is unable to take free oxygen from the air, but can take it after nitric oxide has taken it and altered its rate.

Chemical action is accompanied by either a development or disappearance of heat; and in many cases a change in temperature enables a combination to take place which would not be possible otherwise. Some examples are given in chapter 37. As in gravitation the production of heat results from the collision of bodies, so without doubt the falling together of molecules in chemical combinations is one cause of heat. But this heat is also mixed up with heat from another source; namely, that resulting from the reduction of the velocities of the mole-

cules when combination takes place. When heat disappears in chemical action it must be that it is converted into some sort of work which does not increase temperature. In heating solid bodies it was pointed out at page 401, that part of the heat is used up in giving new positions to the molecules of the solid, and so does not appear as temperature. In the case of gases, heat disappears in giving greater velocities to the molecules of the gas; and according to Meyer (p. 167), when they lose this motion, heat results. If this is correct, and it appears to be, then the movements of the molecules of the gas do not constitute heat. If they did there would be no increase of heat when these motions are arrested. The fact appears to be that when the molecules of a body are dispersed into a gaseous form by a force, there is a division of the effects of the force just as there is when a solid body is heated; that is a part of the energy is manifested in an increase of temperature and a part in this violent oscillation of the molecules spoken of as their velocities. What kind of motion is it then that gives the phenomena of temperature? It must be the motion of the surrounding and intermolecular ether that constitutes temperature both in the solid body and the gas. When a body is spoken of as having such a temperature, it is the same as saying that its molecules which are in a state of vibration are constantly losing a part of that motion which is communicated to the adjacent ether, by the undulation of which it is radiated off as temperature. That is, it does not become temperature till it becomes the motion of ether instead of that of the ponderable molecules.

To sum up, then, in regard to the ether, we recognize it as the connective medium between separated ponderable bodies, as the vehicle of the influences that pass from one body to another, and as the real and essential agent both immediate and remote, in the greater part if not all the motions of the ponderable bodies. It is the active agent in the production of the phenomena of gravitation, electricity, magnetism, chemism, heat, light, sound, nerve action, vitality, and mentality. It is the universal agent of Energy, and the medium in all motion and phenomena. It may with propriety be called the *Soul of Things.*

CHAPTER LXXXVII.

FORCE AND FORM.

It was pointed out in last chapter that the motion of ponderable matter is not heat or temperature, but that this sort of motion (temperature), appears when that of the ponderable body ends. A molecule when it is considered by itself is a mass as truly as a planet is. The motion of a planet through empty space is not heat, and does not give rise to

it unless it hits something; but if it hits another body, as when the earth hits a meteor, the amount of mass motion that is stopped by the collision goes on as heat. But the heat is not all got out of it till all the mass motion is stopped, and that means, when all the separate molecules have ceased to move in whole or in part, and have delivered their motions to their environing ether. The hotness of the body continues in a decreasing degree during this delivery, and ceases when it stops. So we see the hotness is not in the ponderable particles but in the ether. A consideration of this idea will help us to understand the remarkable fact stated on page 337, that the electric arc does not heat. The heat arises when the motion of the mass, whether it be that of a big one or only a molecule, is stopped or diminished. According to the table of specific heats given at page 403, the *atoms* of all solid bodies without regard to their weight are heated to the same degree of temperature by the same amount of heat. The same is true in regard to gases. Equal volumes of all simple gases contain the same number of atoms, and gases in equal volume have the same specific heat. But equal weights of gases differ in the nnmber of atoms they contain, and they differ inversely in the same proportion in their specific heats as shown in the following table, in which the specific heat of water is 1.00, and that of equal weights and equal volumes of the other substances are placed opposite their names.

	Equal Weights	Equal Volumes	Atomic Weights	Atomic Heats
Air	0.237			
Oxygen	0.218	0.240	16.	3.488
Nitrogen	0.244	0.237	14.	3.416
Hydrogen	3.409	0.236	1.	3.409
Chlorine	0.121	0.296	35.5	4.295
Bromine Vapor	0.055	0 304	80.	4.400

In a true gas the particles are not supposed to have any attraction for each other on account of their distances apart, and in oxygen, nitrogen, and hydrogen, there is none of sensible amount. But bromine is a vapor when above the temperature of 63°; below that it is a solid. Chlorine can be condensed to a liquid by a pressure of only four atmospheres; so in these two there appears to be still a degree of cohesive attraction, which a part of their extra specific heat is required to overcome.

Now the explanation given of this uniformity of atomic heats is that when a light atom has a certain amount of heat expended on it, it is set to move off at a certain rate of speed, and if it were not stopped it would continue its flight indefinitely in a straight line. When the same amount of heat is expended on an atom weighing for example sixteen times as much, it too will be started off on a straight flight, but at only one-fourth the rate of speed; the energy remaining the same, the velocities are inversely in proportion to the square root of the masses

moved. Thus, as pointed out page 1,036, hydrogen being one-sixteenth as heavy as oxygen, it has four times the velocity. But these atoms are not at liberty to fly off indefinitely, they immediately come into collision with each other and with the sides of the vessel containing them, and every time they thus collide they lose a part of their velocity, and the part so lost is transferred back to the ether and appears as heat. These heats thus given up are the same for the light atoms as for the heavy ones, because they make up in the number of their collisions what they lack in the force of them. The subjection of a gas to an additional quantity of heat causes the atoms to increase their velocities and their energy of motion, and consequently the expansion of the gas.

We see here the mechanical relationship between the imponderable ether and the ponderable atom. The undulations of the ether are of a force sufficient to hoist the atom or molecule, as a tedder flirts a wisp of hay, or a cotton-gin a wisp of cotton. And the atom is a piece of ponderable matter small enough to be thus flirted and hustled, and that too, at a rapid speed, but still at a speed that bears exact physical relationships to the weight of the atom and the force of the undulations, of the same kind and in the same mathematical proportions, as the relationships borne by the speed of a cannon ball, are to the weight of the projectile and the force of the explosive. It is here, upon these vanishing points of ponderable matter that the energy communicated to and propagated by the elastic ether takes hold, and through them establishes and controls the movements of the universe of ponderable matter.

The following is a list of the elements not mentioned on page 403. The two lists make in all 73 elements, and comprise all thus far discovered. The figures are the atomic weights, hydrogen being 1.

Barium	Ba	136.86	Nitrogen	N	14.01
Beryllium	Be	9.08	Norwegium	Ng	145.9
Calcium	Ca	39.91	Oxygen	O	15.96
Cæsium	Cs	132.7	Rubidium	Rb	85.2
Cerium	Ce	141.2	Samarium	Sa	150.0
Chlorine	Cl	35.37	Scandium	Sc	43.97
Chromium	Cr	52.45	Strontium	Sr	87.3
Decipium	Dp	159.	Tantalum	Ta	182.0
Didymium	Di	145.	Terbium	Tr	171.0
Erbium	Er	166.	Thorium	Th	231.96
Fluorine	F	19.06	Thulium	Tu	170.4
Gallium	Ga	69.9	Titanium	Ti	48.0
Germanium	Ge	72.32	Uranium	U	239.8
Holmium	Ho	162.0	Vanadium	V	51.1
Hydrogen	H	1.0	Ytterbium	Yb	172.6
Lanthanum	La	138.5	Yttrium	Yt	89.6
Niobium	Nb	93.7	Zirconium	Zr	90.4

In the transfer of energy in the shape of heat to the atoms or molecules of true gases in which there is entire freedom from cohesion, no doubt *all* the motion of the actually impinging heat rays is turned into the mass motion of the individual molecules. But in the case of the partly condensed vapors, and the liquids and solids, far less of the

movement of the ether becomes mass motion, and much more is employed in changing the state of the ether in the body acted upon. The undulatory movements of the external ether come into collision with those polar movements of the internal ether that constitute chemical and cohesive attraction, the result being more heat, or the development of electricity; or the elevation of the temperature may promote chemical changes not before possible. Probably in all cases cohesion of the molecules for each other is counteracted, and in nearly all the intermolecular spaces are increased. Solid bismuth, and ice at about the freezing temperature, are exceptions, as they both contract on being heated. The purely mechanical nature of all these movements becomes the more apparent as they are examined, and the continuity of movement from the imponderable to the ponderable takes place evidently not only witnout a break but without the necessity of supposing a form of motion not familiar among ponderable and visible bodies. As the different behavior of the atoms under the impulses of heat is due to difference in their weight which varies from hydrogen 1, to uranium about 240, so there are differences in their chemism, cohesion, &c., due to their *form*, and the way in which their *pieces* are put together. For we are not by any means to consider the chemical atoms as the ultimate condition of matter. Such weighty atoms as those of gold, platinum, tungsten, mercury, lead, bismuth, thorium, &c., must contain much more matter than those of hydrogen, lithium, boron, carbon, nitrogen, &c. In all probability gravitation is an actual measure of quantity in matter. If we should suppose that bodies are endowed with gravitation in different degrees, as they are with chemism and magnetism in different degrees, it would follow that the weights of bodies as they might be carried up from the earth, would vary in different ratios, and the law of gravity would vary in different parts of the universe.

The most reasonable hypothesis is that there are gravitation atoms much smaller than the chemical atoms. Let us call them *atomicules.* They are elemental forms of ponderable matter, whose dissolution, if that were possible, would reduce them to the imponderable ether. They are all alike as to shape, size, and the quantity of matter they contain. Each is surrounded by a definite sphere of the elastic imponderable ether which is endowed with a polar motion that constitutes for the atomicule its attraction of gravitation. This endowment and this motion are still not original states or conditions, but the matter of the atomicule and its sphere all in motion, are specialized particles of the infinite and eternal ocean of ether; as the little whirlpools along the margin of a flood are specialized portions of water. And as the circular motion of the water is a continuation of part of the current of the flood in such new form as the constitution and conditions of the

matter involved necessarily cause it to assume; so the motion imparted to the sphere of the atomicule when it is specialized must take such form as the shape of the body compels. We cannot think of the reflections of force from even an atom without admitting the influence of the form of the body in shaping the direction and manner of such reflection.

The different chemical atoms are made up of the gravitation atoms or atomicules, some containing but few, and others many. Thus the chemical atoms have arisen as aggregations and specializations from the gravitation atoms and have their various forms, and are surrounded by their own spheres of ether whose motion imparted to them at the time of their aggregation and by the force to which such aggregation is due, constitutes their polar chemical attraction.

Every *Fixed Star* visible to us is reasonably believed to be a sun surrounded like our sun by a system of planets. The number of these suns is like that of the grains of sand on a sea shore. The unassisted eye can count several thousand, but the telescope reveals them by the million. They are particularly abundant if we look in the direction of the milky way. This is an immense ring that goes entirely around the sky, and entirely around us, so that we are well in towards the middle of it. There is reason to believe however, that this ring is in reality a flattish disc, like a pie, of small thickness compared to its extent, and when we look toward the milky way in any direction we see this disc of stars edgeways, and so the number in that direction is inconceivably great; but if we look at right angles to the plane of the milky way we see through the disc the thin way, and the number of stars is less. Now as the sun and planets together constitute our solar system, so the disc of the milky way with all the stars belonging to it, including our sun and planets, and all the stars visible to us, constitute *our Stellar System.* It is perfectly legitmate to say *ours,* because as great as it is there is reason to believe that throughout its vast extent, matter and its properties are everywhere substantially the same as in our little solar system. The universal ether puts us in touch with the whole of it, and enables us by means of the telescope to observe the motions of distant stars to be in accordance with the same law of gravity that keeps us from being flung off the surface of the earth; and by means of the spectroscope we discover that there are to be found in bodies whose light has been years on the way to reach us, many of the same elements that we dig up in our fields and mines. Certainly our stellar system is one family; and the cause that imposed not only ponderability but also chemism upon the materials of our sun and planets, was a catastrophe that involved the entire stellar system; and no doubt it will take another equally vast and far reaching to undo

those effects. The chemist has not been able to permanently disintegrate an atom of any one of the 74 elements that are no doubt common to the whole system.

But there is no reason to suppose these atomic conditions and propties to be confined to our *little stellar system.* All magnitudes are comparative, and our stellar system big as it is, is small compared with the *Universe.* Outside of our stellar system, and separated from it by distances equal to a million times its diameter, are other stellar systems, up and down space, in all directions—thousands of them. The ether stretches away to all of them; for otherwise we never could see them; and there can be no doubt that weight and chemism, atoms and elements go with it, built out of and upon it, as the stratified rocks of the earth's crust have been derived from mother granite.

How far does the ether extend beyond the most distant nebulous stellar system that our telescopes reveal? Space is infinite. We cannot comprehend infinity, but we can conceive of it, while in this case we cannot conceive of limits. Is ether likewise unlimited? Or has it a border or sort of tough selvedge which binds it all around, and from which are reflected back the waves of the vast web within? Is it here that the eddies of the billows rolled back upon themselves form the gravitation atoms? Or are these the products of the clash of vast waves rolled together in the mid-ocean of ether? Or may we imagine the final margin of the ether to be without selvedge or binding, and like the frayed edges of a web, to become worn and snapped off by the undulations of the mass within? Do the particles thus snapped off thereafter constitute independent atoms, and does the force expended in their severance become to them their polar energy of gravitation? Would they thus be drawn to each other across constantly lengthening chords of the spheroidal universe of ether, till finally their aggregated masses would plunge through it in all directions? If the ether is unlimited may not the process of the evolution of the gravitation atoms or atomicules, the creation of "cosmical dust," the erection of new nebular and stellar and solar systems, be still in activity to continue thus forever? Has this process been going on forever in the past? Or did it have a beginning? If it began at a certain time, why did it not begin sooner? Are the collisions and smash-ups that happen between ponderable bodies, such as we see when a meteor strikes the earth, ever great enough to reduce the ponderable bodies to ether? If so might we not conceive the process of making and unmaking of stellar systems to have gone on during all time past, and to continue for all time to come even with a limited area of matter?

But how came ether to be in existence in the first place, and being in existence, how came it to be in motion? Did it always exist, or was it

made? Did a Creator make it? If so, what did he make it out of, and where did he get his material? If he set it in motion, where did he get the energy? Is the energy he had in the beginning, reduced by the amount communicated to moving matter, and he therefore that much weaker? Can he lose energy to matter and recover it again from matter as a man does? Could he do this without being matter himself? How did *He* come into existence, and when?

Do the operations of the attraction of gravitation require to be watched in order to render them effectual?

The last question is an easy one, and so we answer it. Certainly not; gravitation will cause bodies to fall toward each other, night and day, just the same whether any one is looking on or not. As asserted in the last chapter, all the motions of every sort that we are acquainted with, have arisen directly or indirectly from the force of gravity. They are all continuations and extant reverberations of the energy of fallen bodies. If the body will fall without supervision the consequences of the fall will occur equally without outside interference, and we may legitimately conclude that every motion that we know anything about, because it is only an echo and rebound, is as necessary and inevitable as the blow or fall of which it is a continuation.

In foregoing chapters it has frequently been pointed out that the differences in forms of motion depend upon the character and form of the body to which the energy is applied. This must hold good from the minutest particles to planets, suns, or even stellar systems. A new distribution of energy in the solar system would cause a new adjustment of the position of the planets. On the other hand the forms of bodies are determined by the action of the force upon them or upon the materials from which they are formed.

If we break a piece of ice, a piece of wood, a piece of cast iron, a piece of steel, a piece of sandstone, we find the surfaces of the several fractures all different, and these differences evidently depend on the way in which the particles are joined together by "cohesion," and this in turn must depend on the shape of the particles, and this again upon the elements involved, and their polarities. The difference between the cellular and fibrous tissues of plants, arises from difference in the form of the cells. The cells of a moss for example, are spherical, those of a hemp are long and tubular, which is sufficient to account for the difference in texture and toughness of the two plants. A piece of pine splits easily the long way of its cells, but not the cross way, which it would do if the cells were no longer than they are wide. If the cells of the wood were all the same length and placed so their ends were even with each other, at these ends there would be places of easy breakage. But they lap past each other or break joints, consequently the

cells cannot be separated crosswise by a straight line. So that owing entirely to the shape of the cells and the position which they occupy toward each other, the cohesion of the wood is very much greater lengthwise than crosswise. When iron is rolled it becomes stringy and tough in the direction of the rolling and brittle across the "grain," its molecules or particles are forced into a shape and position analogous to that of the wood cells, and like the wood its cohesion is much stronger in one direction than in the other. Those qualities of bodies which depend upon the relative position of their particles toward each other, are the effects of some sort of energy to which they have been exposed. Thus steam, water and ice are three forms of the same substance under various forms of condensation depending upon temperature.

The difference in the effects upon light in its passage through crystals was pointed out (on pp. 397–398) as due to the peculiarities in the molecular structure of the crystals. We have refraction, reflection, absorption, selective absorption, plane and rotary polarization, and other phenomena obviously due to the way in which the molecules of the body are put together, and consequently the form of the intermolecular spaces. The undulations of the ether when they reach the crystal from a luminous body obviously communicate motion to the ether in the body. If this motion is propagated through the body, and communicated to the ether beyond, the body is transparent. When a part of the motions of a beam are absorbed and a part transmitted, or reflected, the body appears of the color of the transmitted or reflected rays.

The molecular constitution of bodies also governs the manner in which they are affected *by* heat (see pp. 400, 401) as well as the quality, that is, the wave lengths of heat they emit when hot. Instead of rays in a *continuous* progressive series of wave lengths the body may emit a selected assortment or *discontinuous* series, missing some here and there.

Form also governs in regard to sound, as pointed out pp. 375 to 378, and in chap. 86. The different shapes of the various instruments of music cause the different sorts of sound when acted upon by appropriate forms of energy. Different lengths of strings, or reeds, or pipes, give sounds of different pitch, etc. Not only the mass-form of the instruments, but also the molecular arrangements of their materials are concerned in the production of variety in sounds, causing harmonics, &c. A silver bell has a very different sound from that of an iron or copper one.

It happens in many cases that the application of energy to a body results in changes in the body itself, as well as in giving new forms or directions to the motion when reflected from it. Considerable hills or dunes of sand on some sea coasts are moved by the action of the wind

which raises the sand on the windward side of the hill and blows it over the crest where it settles in the still air under shelter of the lee side. The hill thus gradually proceeds across the country, the wind following it up. Similar action is caused by water currents, that change channels, thereby changing their own direction.

Analogous to this is the action of the molecular energies, such as magnetism, chemism, nervous energy, mentality, &c. All of them tend to work alterations in the instruments upon which they operate and thus to cause modifications in the phenomena or functions resulting from their operations.

"When a steel or iron bar is powerfully magnetized, it grows a little longer than before, and since its volume is the same as before it at the same time contracts in thickness. Joule found an iron bar to increase by $\frac{1}{720\,000}$ of its length when magnetized to its maximum. This phenomenon is believed to be due to the magnetization of the individual particles, which, when magnetized, tend to set themselves parallel to the length of the bar. This supposition is confirmed by the observation of Page, that at the moment when a bar is magnetized or demagnetized, a faint metallic clink is heard in the bar. Sir W. Grove showed that when a tube containing water rendered muddy by stirring up in it finely divided magnetic oxide of iron was magnetized, the liquid became clearer in the direction of magnetization, the particles apparently setting themselves end-on, and allowing more light to pass between them. A twisted iron wire tends to untwist itself when magnetized. A piece of iron when powerfully magnetized and demagnetized in rapid succession grows hot, as if magnetization were accompanied by internal friction." [1]

The molecular structure of metals controls their conductivity of heat and electricity, the resistance being much greater in some metals than in others, but practically the same for heat that it is for electricity. When a current of electricity is sent through a poor conductor, the resistance turns the electricity to heat. As Prof. Tyndall pictures it, the current exhausts itself by knocking against the obstructing molecules in struggling to get past them. In the case of the good conductor the molecules lie in positions to allow of easy movement to the ether, and so the current gets by without disturbing them or heating them. It is settled that the conduction of electricity in a perfect conductor is the same as that of light in ether; viz., 186,000 miles per second. (See page 345).

Attention was called at the beginning of chapter 37 to the influence of the *form* of the molecules of bodies on their *chemical* reactions. This is without doubt to be attributed to the directive influence of form

[1] S. P. Thompson, Electricity and Magnetism, p. 93.

upon polar currents. (See page 500). The currents of a molecule of a certain shape will be changed when the atoms of the molecule are rearranged to give it another shape, although the atoms remain the same in number and kind. This is illustrated by the change in the valency of bodies by change in temperature mentioned on page 1035. The valency depends on the number of bonds, which depends on the polar currents, and finally these depend on the shape of the molecules.

The apparent differences in property between the different forms of allotropic, isomeric, and polymeric bodies (see chap. 37) are obviously due to differences of molecular forms caused by energy in the shape of heat, light, electricity, &c. These agencies likewise effect changes in bodies that alter their power of absorbing light and heat and cause alterations in the wave lengths of the light they emit when made incandescent.

This is shown in spectrum analysis (see page 404). When a solid body is heated to incandescence, and its light passed through a narrow slit and a prism, the spectrum it gives will be continuous, the colors running from red into orange, yellow, green, blue, indigo, and violet, fading from one to another without gap or break. In this case it is obvious that the body is emitting waves of light of all or most of the lengths in the 44th octave, and this must mean that the particles of the body are then in such a variety of shapes and held together in so many various ways, that the ether of the spaces in and about the particles vibrates in all those different tones. Now as the dispersion or separation of the molecules and atoms becomes great enough by the elevation of the temperature, or the action of electricity to turn the solid body into a vapor, the spectrum changes. It becomes discontinuous, there being only a number of lines across the spectrum, some being of one color and some another, and separated from each other by colorless spaces. This is also the character of the spectra of those bodies which are gases at the ordinary temperature. Between these two sorts of spectra most bodies show an intermediate spectrum composed of bands. The band spectrum is produced by a temperature less intense than that producing the line spectrum.

The explanation of these differences in the spectra of the same body at different degrees of temperature is that the particles of the body are in different states of aggregation, both as to compactness and form. When a body is cold its aggregation is greatest, all its particles hanging together, as in a chunk of pig iron or piece of platinum. There is even at the ordinary temperature a certain degree of separation between the particles, entailing upon them a degree of activity which is constantly being given up as heat, and as constantly renewed by fresh accessions from the temperature outside. The waves of this tempera-

ture are probably those of the 27th to the 29th octaves, far below the visible octave. I conjecture, that at these low temperatures the immediate subdivisions of the solid body are not molecules but aggregations much larger than molecules, composed in fact of many molecules held together by cohesion. These aggregations may be called *moles*; a term meaning masses. These moles then are of great variety in size and shape, and they generally maintain their organization up to the temperature of white heat. At red heat temperature those of them that happen to possess the proper fundamental pitch vibrate in the red tones, that is waves of the lower end of the 44th octave; or rather they vibrate at such rates as to communicate such motion to their ethereal spheres. When the body is subjected to the temperature of white heat all the moles set up vibrations in their ether, and the result is the radiation of light in all the wave lengths of the 44th octave. When the temperature is raised above this some of the moles are resolved into their constituent molecules, and this process increasing with increasing temperature, the variety of these aggregations is constantly lessened, the spectrum showing discontinuity as they are broken up.

It would seem reasonable to suppose that if all the particles in a body were of the same size and form, their activities would give rise to the same sort of radiation, that is light of the same color. That it does not, is proof of a difference in their modes of activity, and this in turn may be accounted for by the hypothesis of the moles in various shapes and sizes. The different states of a body under the different temperatures may be considered as quasi allotropic, isomeric, or polymeric. (pp. 348–351). But even in the gaseous state and incandescent, every body still emits waves in different lengths, and so marks lines on the spectrum in various numbers from four in hydrogen to many hundreds in iron. The spectrum of nitrogen is changed completely by change of temperature at high degrees, and this has been explained by supposing nitrogen to be liable to various allotropic states. (Roscoe.) This has also been found to be the case with other gases. Another extremely important fact is that gases when greatly condensed give continuous spectra. When hydrogen was placed by Lockyer in a vessel connected with an air pump, and then some of it pumped out so as to make the residue rarer, its lines across the spectrum became narrower. On the other hand when more hydrogen was pumped into the vessel so as to make it more dense, the lines began to widen, and continued to widen as the pressure was increased, until finally they touched each other, forming a continuous spectrum. (The ordinary spectrum of hydrogen consists of four bright lines, one very bright *red* line, one bright *greenish-blue* line, one dark blue or *indigo*, and one *violet* line that only comes out when the temperature is high. See table p. 383). In

the case of magnesium vapor, increase of pressure widens the lines of its spectrum and also increases their number. In general, increase of pressure in vapors and gases causes a widening of their spectrum lines. Increase of the temperature of solid bodies increases the kinds of light they emit, but such increase in the temperature of a vaporous or gaseous body does not change the quality of the light. When *pressure* is increased molecules are pressed into moles; and in vapors that are upon the point of condensation into liquids or solids, the moles are in the greatest variety of size and form. When *temperature* is increased in solids the moles are in process of disintegration back to molecules.

The fact that hydrogen marks four disconnected lines for its spectrum, makes it exceedingly probable that the molecules or moles of hydrogen are of four forms, and that the atom is really compound. The atom of hydrogen is much lighter than that of any other element. Most of the elements also mark more lines on the spectrum; and so it should be inferred that the *atoms* of all elements are *compound*. This is the view taken by Mr. Lockyer a number of years ago, and which he supported by many arguments drawn from spectrum analysis. As pointed out above, this view is demanded by the fact of the differences in the atomic weights of chemical atoms, making it necessary to recognize the gravitation unit or atomicule. It is confirmatory of the views given here that compound bodies give spectra of their own, and as peculiar and characteristic as those of the so-called simple bodies. The spectra of such compounds as iodide of strontium, or chloride of strontium, or bromide of strontium, consist of fluted or channelled spaces and bands, and these increase in number as the bodies are made more dense, just as in the case of simple bodies.

As observed before, the temperature at which the combinations of atomicules in the formation of the chemical atoms originally took place, was greater than the chemist is now able to reproduce, and so the chemical atoms have not been undone.

We have every reason to infer that there is no difference between the atomicules in their mass and form, and consequently in their reactions against force. But as soon as they are combined together in the formation of different shaped bodies, their movements under the impulses of force become different. This is a reasonable inference, and is abundantly supported by the facts of allotropism, &c., mentioned in chapter 37. In such cases it is evident that new properties or reactions are brought about by a change of form, and occur as soon as such change is effected.

It is from want of recognition of the essential qualities of form and size of the body moved, in all cases of motion, that has led to the notion of discontinuity in the causation of things. The instant a change

is effected in the molecules or moles of a body, that instant it becomes to all intents and purposes a new body. But it is not therefore something made from nothing. If two different bodies be consolidated into one, the result is also a new body, and the form may be totally different from that of either of the constituents, and the properties and reactions totally changed. A man may tear down a brick house and with the materials construct a bake oven, an arch bridge, or a smoke stack; or he may take some pig iron and melt it and make it into a steam-chest, a cook-stove, or a gas-pipe. Without changing the material, a simple alteration of form makes a radical difference between the functions or reactions possible to the body; and this consideration applied to chemical elements leads to the conclusion that since change of form alone is proved to be productive of change in chemical properties, therefore form alone constitutes the difference between bodies; and that when reduced to their simplest forms, viz., atomicules, all *bodies* are alike; and that therefore before bodies are differentiated from the original ether, all *matter* is alike.

The change of reaction and function that supervenes upon a change of form is often of the most radical and extreme nature. The change of form may take place very suddenly and quietly under the impulse of external energy. But still it is surprising that any of these changes however swift and magical, should nowadays mislead any one to introduce the supernatural into his notions of their causation. But still they do. Mivart says, "Universal and persistent continuity in nature does not exist." He gives as examples of "interruptions" the separation of the embryo from the body of the parent, and the impregnation of an ovum "wherein there is and must be an instant before and an instant after the contact of the ultimate sexual elements." He holds with Wallace that a "new cause or power" must have "come into action" "at the origin of life and sensitivity as well as at the origin of man himself." He and Mr. Wallace also agree "in affirming the active agency of immaterial principles in bringing about the phenomena of nature, organic and inorganic. But if the necessary intervention of an intelligent immaterial agency be accepted to account for the origin of any part or power of the material world, why not also for the origin of man?"

It seems to me the effect of the above view is to introduce the supernatural and miraculous into every chain of causation where any link of such chain may happen to be obscure to our apprehension. For if this notion is admitted anywhere it must be everywhere. If every apparent "interruption" in the continuity of causation like the above, is to be bridged over by a supernatural intelligence, it must officiate at the birth of every individual, because the distinction of race is got only by the

distinction of individuals. Every son differs from his father, and the break which separates races from each other is narrowed finally to that which separates father and son. Race distinctions are purely artificial, adopted for our convenience, and do not exist in nature. Traced backward from son to father we reach in all of them the common protoplasmic origin, where all organic nature is tied together. But equally are the distinctions of organic and inorganic artificial. We cannot discover any break in causation between the two. That new modes of action result whenever a body is placed under the influence of new forms of energy, or when a new body is formed by combinations of older ones, is a statement that covers all departments of nature, joins them all together, and obliterates all artificial boundaries between them.

Whenever a chlorophyll cell takes a molecule of carbon from the carbonic dioxide in the air and incorporates it with the tissues of a plant, it transports a particle of matter over the imaginary boundary between the inorganic and the organic. Analyze a human body, and there is not a particle in it that has not been thus transported. There has been no change in the constitution of matter by this transportation; no alteration from an inorganic matter to an organic matter. A cow may eat a plant, and one of the molecules of carbon contained in it, pass through her milk-glands and become after awhile part of a pound of butter; next, it may become part of the brain tissue of a man; and, later, it is worked off and burnt; that is, in the blood it meets its old companion, oxygen, again, and with it forms carbonic dioxide, and then is carried into the lungs and dumped back again into the air from which it came. In all this round, the molecule has not for a moment lost its identity or its nature. It has formed part of first one body and then another. But there is nowhere any break in causation with reference to its transpositions. The forms of the bodies it has belonged to have determined the several modes of reactions and functions in which this molecule has been concerned. Even as a single molecule it is an organism, as pointed out on page 347, and is liable to be operated by certain forms of energy, and to react in ways peculiar to its constitution.

What is said here of this element is true of all. In their simplest forms they are simply organized, and react in a correspondingly simple manner against simple forms of energy. As they become involved in complicated combinations in the formation of more complex organisms, all the conditions become more varied, and the reactions more involved. But no change of principle takes place from beginning to end. It is not possible to designate any change that takes place in form or function as resulting from causes disconnected from physics, or to show that such changes may take place in the absence of previous physical causation.

The union of the sexual elements in the formation of a new body, mentioned by Mivart as a sample miracle, is as explicable as any other chemical reaction. Take, for example, the formation of hydrochloric acid, or muriatic acid, as it was formerly called, mentioned on page 409. Hydrogen is the lightest of all gases, and is without odor, color or taste. It is scarcely soluble at all in water, as 100 parts of water will take in only about 1½ parts of the gas. Chlorine is a yellowish-green gas of suffocating odor, and astringent taste, about 2½ times as heavy as air and 35½ times as heavy as hydrogen. It is fairly soluble in water, one volume of water dissolving three volumes of the gas. When equal volumes of these two gases are united, they form muriatic acid which is a colorless pungent acid gas. This gas, considering its constituents, is astonishingly soluble in water, *one volume* of water absorbing *no less than 450 volumes* of the gas at 15°. This solution is the liquid acid. Here then we have by the expenditure of force upon two bodies, a product totally different in mechanical structure and *therefore* totally different in function from either of them.

Again consider water, formed of two volumes of hydrogen and one of oxygen. Oxygen is a gas 16 times as heavy as hydrogen, so that it composes eight-ninths of the water. It is also one-half of silica (quartz, sand, &c.,) and one-third of alumina (clay). "Fully ½ of the weight of all minerals, ¾ of the weight of all animals, and ⅘ of the weight of all vegetables is oxygen" (Barker). It is the supporter of all animal and vegetable life; all human life would cease inside of 30 minutes if oxygen were suddenly eliminated from the air. Oxygen supports our lives by slowly burning us up. As the product of this combustion and that of burning wood, coal, &c., is carbonic dioxide (CO_2), this gas may be called burnt carbon. In like manner water is burnt hydrogen. Both the gas (CO_2) and the liquid are used to put out fire because neither of them can be burnt any more thoroughly than it is; and a man can be drowned with equal facility in either. Water is more than 11,000 times as heavy as the same volume of hydrogen, and nearly 700 times as heavy as oxygen, showing both an enormous condensation of the materials and change in molecular structure in the formation of the liquid from the gases. The properties, reactions, or functions of water differ as radically from those of its constituent gases, as its new molecular constitution differs from theirs, and we have no hesitation in affirming; *because* it so differs.

Again take a pair of common seidlitz powders; dissolve each separately in half a tumbler of water. The two solutions give no indication by their quiet and demure appearance, of the hubbub they will raise when the contents of one glass are poured into the other. The effervescence that then takes place is caused by the escape of carbonic

dioxide (CO_2), which is produced by the oxygen of the acid powder, burning the carbon out of the bicarbonate-of-soda powder. Each of the bodies used here being a compound, the reaction is a little more complicated than the former examples, two bodies being produced instead of one. But hardly anybody will be likely to contend because there was an "instant before and an instant after the contact" of these elements, between which instants bodies of new forms were constructed from the old ones, that there was therefore a discontinuity of causation, and the interference of some agency outside of natural forces. The obvious conclusion is that the body formed by the combination of others is usually of a form or quantity differing from that of either of its constituents; consequently the currents about it which constitute the machinery of its attractions and lie at the bases of its functions of gravity, chemism, magnetism, &c., are made to differ in quantity, or take new directions; while all these new conditions entail certain changes in the manner in which the body will react against the impact of force from without.

It is true that it is often difficult to trace the manner or determine the cause of a change, in terms of matter and motion that we are familiar with. But the difficulty is not mended by assuming that the natural manner and cause had come to an end and ceased to exist, and that thereupon supernatural powers had stepped in and caused a new start on the other side of the break. Such an assumption might be admissible as an alternative proposition to stand its chance with a counter assumption that the break in natural causation is apparent only, and not real; provided it could be shown that there are occasional cases in which supernatural agency can be *proved* instead of being merely *assumed.* An assumption that cannot give references of this kind is an assumption without character. It may ask and receive toleration, but it has no logical claim to consideration or confidence. We have abundance of instances in which natural causation can be traced and proved through surprising and remarkable changes; and assumptions that refer to these as analogies have a claim to attention and comparison. But an assumption of supernatural agency has no analogy with anything unless it be another equally unprovable assumption.

A *vital organism* is a synthesis or composition of several bodies which, considered separately, give reactions that are to be classed as chemical or physical; and which in the bodies so associated occur in such a way as to mutually support and perpetuate each other. Such synthesis is the result of the actions and reactions of energy in its alternate transfer from ponderable bodies to ether, and from ether to ponderable bodies. The vital organism is a target for every form of energy darted through its environment, and in its growth, development,

and evolution it is a product of such forms of energy. Made up itself of a combination of ponderable and imponderable matter, it is a specialized portion of the great universe which in whole and in part is everywhere of like composition. When the reactions of the several portions of a vital organism no longer support each other, there is nothing to hold them together and they fall apart. But the dissolution of the partnership that constitutes the organism does not involve the death of the ultimate pieces. The energies that place the particles in the organism with such marvelous adjustment; that cause their actions and reactions while in such combination and which finally remove them —these energies never rest. The molecules never die. The end of one combination is the beginning of another. There is no pause nor interregnum. But the dissociation of the particles of the organism is accompanied by that of the various forms of energy to whose aggregation we give the name *vitality*. There is no *vital force* considered as a single mode of motion. Vitality ends as vitality, when the organism ends as an organism.

While we cannot conceive of energy ever beginning from a state of no energy either as the result of an accident or of a fiat, we readily perceive the influence upon the details and particulars of its phenomena exerted by the *forms* of the bodies in connection with which these phenomena occur. The ether is admitted to be the universal vehicle for the conveyance of energy between ponderable bodies not in contact with each other. When one such body is in motion the force of that motion is communicated to the ether, which in turn communicates it to other bodies at a distance. This it may do by one of the three modes of movement possible to itself, viz., the undulatory, the pulsatory or the current. The sort of motion communicated to the ether by the delivering body is such as the form of the body itself causes it to affect, and the sort of motion set up in the receiving body depends upon the nature of such body as to shape, size, and the qualities that determine its fundamental pitch. A mode of motion or a tone that affects one body will have a different effect or no effect at all on another. The reactions of the many different kinds of bodies against the thousands of tones of impact possible to be delivered by the ether, together constitute in themselves and cause in other bodies all the phenomena of motion we are acquainted with, each sort of motion receiving a name significant of the body moved or the kind or tone of the motion.

A gun does not furnish the force by which the bullet is driven, but it is essential to the effectiveness of the force; and its form, weight, position, &c., determine the quantity of force that may be used and the direction the bullet will take. Powder burnt in the open air would produce a very different effect. Fire-crackers, Roman candles, rockets,

pistols, shot-guns, mortars, bomb-shells, torpedoes, cannon, &c., represent different forms of bodies related to gunpowder and its gas when it is exploded, each causing a different effect due to its peculiar form and constitution. In like manner the ponderable bodies constitute the bases of the action of the ether; and their form, structure, and molecular constitution determine the manner and force of its manifestation. Its impact sets the individual molecules of bodies in motion, and its currents around all particles establish their gravity and chemism. Its motion in magnets is magnetism. Its motion in batteries and conducting wires is electricity, galvanism, &c. Its motion in the nervous systems of animals is nerve action; in their brains and ganglions its motion is mentality of various kinds, depending upon the class of cells from which its reaction takes place. From one it is warmth, from another heat, another light, or red, or green, or blue; from others it is sounds in hundreds of tones and hundreds of qualities, as those of bells or voices, or breezes, or brooks. In short it is sensation of all kinds. From others its motion is the result of the reduction and consolidation of sensations, constituting the forms of mentality known as perception, ideation, reason, &c. In short its reactions from brain cells constitute *Mind*.

The brain itself constitutes the soul—the seat of mentality. Ether appears to be the common carrier of energy, transferring it from one end of the universe to another.

INDEX.

ABBREVIATIONS.

Br. brain; *Dev.* development; *Diff.* differentiation; *Ef.* effects; *Exp.* experiments; *Opt.* optic; *Quo.* quotation. Words in italics are definitions of the preceding word. This * refers to page in which subject is explained.

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